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Geoscience in policy making: past experience, current practice and future opportunities

Contents

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We would like to express a particular thanks to all those who participated in the peer reviewing of this issue and thus contribute to the improvement of the standards of the European Geologist journal. The articles of this issue have been reviewed by Arda Arcasoy, Roberto Alvarez de Sotomayor Matesanz, Eleni Gianni, Christos Karkalis, Nenad Maric, Péter Scharek, Monica Sousa and Ratko Vasiljevic.

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Foreword

EurGeol. David Govoni, EFG President

Dear All,

I have been asked to write an introduction about how geoscience contributes to policy making.

I believe a good start would be to share a text I wrote in 2005, as a recent graduate when I served as president of the Young Section of the Italian Geological Society. The text relates to an initiative we organised in my city—a debate among mayoral candidates about geo-environmental topics.

At the time, engaging in political debate was criticised upon by some senior scientists, who deemed it inappropriate for a scientific organisation. Despite criticism, my fellow colleagues and I, as young graduates, received support and persevered. The following year, the same initiative was repeated in another city.

(Translated from Italian - 2005)

"I want to bring up one definition of engaging in politics: the activity of those who participate in public life.

With this in mind, I would like to ask: is it right for us, as geologists, as a scientific community, to participate in public life?

We cannot complain about the lack of visibility and consideration for Earth Sciences if there is no real willingness to participate in public life. We must engage with the administrative world. It is crucial to have a presence at administrative discussion tables, not just technical ones.

As young professionals and researchers in Earth and Environmental Sciences, we must bring territorial and environmental issues to the attention of administrations, approaching these topics from the perspective of those dedicated to Earth Sciences.

Our involvement in the debate on the country's governance has a dual purpose for our community:

- *Advancing Earth Sciences;*
- *Improving working conditions of those involved in Earth Sciences.*

I believe our technical-scientific community must express a cohesive stance on merit-based choices to make our ideas felt, and, above all, to contribute to socio-economic development. This should be done with utmost independence, transparency, and based on concrete ideas rather than empty slogans.

There are too many frequent issues concerning the territory that lack direction, an opinion, or a request for geologists' intervention. I will not dwell on these well-known and extensively discussed problems, but I will suggest a solution.

In light of the administrative elections on 2 and 3 April 2005, we organised a public debate on March 25 at 8:45 p.m. in Pavia with mayoral candidates on the theme of "territorial and environmental policies for the city of Pavia." The event took place at the Sala Grande of the Borgo Ticino Library (former headquarters of the Circoscrizione).

The discussion, prepared from a geological perspective, will focus on the concrete programs and choices of the candidate groups regarding these aspects of public administration.

We want to know and discuss with those who will govern the municipality and the territory of Pavia, understanding the directions in their programs concerning these issues. A detailed discussion is essential. Pavia is an important city, home to one of the oldest universities in Europe, traversed by the Ticino River, with well-known flooding problems, including within the Ticino Park, and it is crossed by numerous watercourses.

It is expected that those who will govern should be chosen based on the programs they choose to implement in these sectors.

The goal, aside from bringing clarity, is to question (in a non-polemic but constructive manner) any positions where there is an evident discrepancy between intervention programs and widespread technical-scientific knowledge in the field.

I understand the risks and difficulties of bridging politics and geology and the potential for these initiatives to deviate from their intended course. However, as mentioned earlier, this initiative has a very specific purpose: to find a way to influence political choices and promote the social role of our discipline".

After 18 years, I continue to believe that as a professional and scientific community, we have the opportunity to engage at various levels – both local and national – in the political election debates across Europe. This engagement aims to ensure that the topics of our discipline are integrated into electoral programs, and the candidates' positions on these topics are clear. This ensures that citizens and society can make informed choices based on the candidates' stance on issues such as, energy policies, land use, urban planning, natural hazards prevention, etc. Moreover, when there is an evident discrepancy between intervention programs and widespread technical-scientific knowledge, this should be highlighted in a non-polemic but constructive manner.

This is one of the potential contributions of geoscience to policy making.

Kind regards,

David Govoni
President of EFG

Geology in legislation making: Past experience, and future opportunities in Europe

Tamas Hamor [1], Pavlos Tyrologou [2] and Maria Hamor-Vido [1]*

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In the last century geoscientists played a limited role in shaping mainstream legislation. Their assistance was limited to drafting the technical aspects within regulations governing the extractive sector or waste disposal. Their primary responsibility was the implementation. A significant shift occurred at the turn of the century. Driven by rapid developments in the EU acquis on environment and energy, emerging political priorities, and professional associations became successful in horizon scanning and proactively proposing scientific and technical aid to EU bodies. Foresight studies now warn for potential conflicts, both physical and legal, arising from diverse sectoral legislation governing underground space and extractable geological resources. The current first-come-first-serve practice is not in compliance with the principles of good governance and prudent management of natural resources. A pragmatic solution involves the harmonised application of the Strategic Impact Assessment Directive and the transition of 2D land use planning into a 3D (4D) spatial development. This requires the guidance of national authorities by the EC to ensure good governance and a collaborative awareness-raising campaign by industry and professional associations, including EFG.

Au siècle dernier, les géoscientifiques ont joué un rôle limité dans l'élaboration de la législation dominante. Leur assistance s'est limitée à la rédaction des aspects techniques des réglementations régissant le secteur extractif ou l'élimination des déchets. Leur principale responsabilité était la mise en œuvre. Un changement important s'est produit au tournant du siècle. Poussés par l'évolution rapide de l'acquis de l'UE en matière d'environnement et d'énergie, les priorités politiques émergentes et les associations professionnelles ont réussi à analyser l'horizon et à proposer de manière proactive une aide scientifique et technique aux organes de l'UE. Les études prospectives mettent désormais en garde contre des conflits potentiels, tant physiques que juridiques, découlant de diverses législations sectorielles régissant l'espace souterrain et les ressources géologiques extractibles. La pratique actuelle du premier arrivé, premier servi n'est pas conforme aux principes de bonne gouvernance et de gestion prudente des ressources naturelles. Une solution pragmatique implique l'application harmonisée de la directive sur l'évaluation des impacts stratégiques et la transition de l'aménagement du territoire en 2D vers un développement spatial en 3D (4D). Cela nécessite l'orientation des autorités nationales par la CE pour garantir une bonne gouvernance et une campagne de sensibilisation collaborative de la part de l'industrie et des associations professionnelles, y compris l'EFG.

En el último siglo, los Geocientistas han jugado un rol limitado en dar forma a la legislación general. Su participación ha estado limitada a la redacción de aspectos técnicos de reglamentos relacionados con el sector extractivo o manejo de residuos. Su responsabilidad principal fue la implementación. Un cambio radical ocurrió hacia finales del siglo. Motivado por rápidos cambios en las políticas de la EU en medio ambiente y energía, prioridades políticas emergentes y asociaciones profesionales, resultaron exitosas en escanear el horizonte y proponer en forma proactiva, ayuda científica y tecnológica a los organismos de la EU. Estudios con miras de largo plazo advierten de potenciales conflictos, tanto físicos como legales, que surgen de diversos sectores de la legislación que regula el espacio subterráneo y los recursos geológicos extraíbles. La práctica actual de "primero en llegar, primero en ser atendido", no cumple con los principios de buen gobierno y manejo adecuado de los recursos naturales. Una solución pragmática implica la aplicación armonizada de la Directiva de Evaluación del Impacto Estratégico y la transición de la planificación 2D del uso del terreno, a un desarrollo espacial 3D(4D). Esto requiere la guía de autoridades a nivel nacional de la EC para asegurar una buena gobernanza y una campaña colaborativa de sensibilización por parte de la industria y asociaciones profesionales, incluida la EFG.

1. Introduction

Foresight studies on future research tasks of geologists have been published mainly in association with major milestones such as the millennium [1] or in response to rapidly emerging challenges [2]. However, significantly less attention was paid to past and future regulatory involvement of geologists. While monographic papers have explored the provisions of the European Union (EU) Community legislation ("acquis") pertaining to mining [3], soil and subsoil [4], extractive waste management [5], unconventional hydrocarbons [6], certifying professional geologists [7] but pan-European reviews addressing relevant permitting issues and regulatory authorities fora are notably scarce [8, 9, 10].

As a validated hypothesis, the societal and economic importance of a discipline and a profession, inter alia, can be assessed by its occurrence in national and European Union legislation, as well as in precursor policy documents. The initial attempt was by Hamor [11], who traced the evolving responsibilities of the geological authority over the past 170 years in Hungary. Comparable methodologies have been deployed in works examining a half-century timespan of EU law, addressing issues on oil and gas [6], and

[1] University of Pécs
[2] European Federation of Geologists
* hamort4@gmail.com

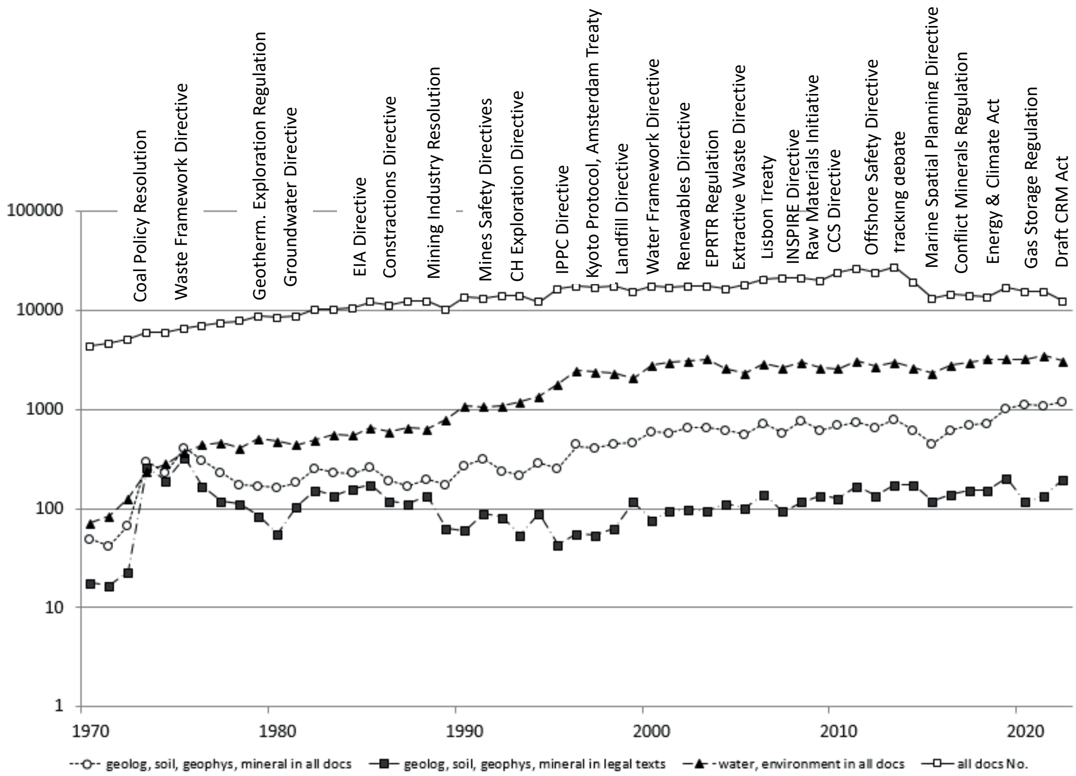

Figure 1: The graph illustrates the annual count of published legal and policy documents in the European Union related to environment and geology, between 1970 and 2022. The data was obtained through a text search in the EUR-LEX online database (adapted from Hámor et al. [12]).

providing a comprehensive overview on geology in a broader context [12].

Building upon the aforementioned works, this study aims to provide a conclusive historical review of the evolution of the acquis over the past half century. It focusses specifically on topics that require the involvement of geologists and competent geological authorities in the entire legislative process, in its implementation, monitoring and post-implementation aftercare. The proxy analysis highlights major political and economic milestones, as potential drivers, and also points at a possible regulatory solution that may mediate most potential conflicts in the future. It is stressed that the focus of this paper is on legislation in a strict sense and not on the voluminous policy documents. The current study and the earlier works of Hamor et al. identified approximately 200-300 relevant legal pieces, the display of which is beyond the size limits of this article.

2. Materials and methods

The EU acquis is referred to as "*supranational*" law. Its primary legislation includes treaties and international conventions. Treaties regulate the thematic scope of the acquis, the responsibilities of EU bodies and the legislative, executive and judicial procedures. Secondary law includes: (a) regulations, directly applicable and binding in all MS; (b) directives, binding the objectives to be achieved, while leaving national authorities at discretion; and (c) decisions, binding for those to whom they are addressed. Union competences are governed by the principles of subsidiarity and proportionality. In areas outside of its exclusive competence, the Union acts only if and in so far as the objectives of the proposed action cannot be sufficiently achieved by the MS, whether at central, regional or local level. The Union intervenes when, due to the scale or effects of the proposed action, achieving these objectives at the Union level would be more effective (Treaty on the Functioning of the European Union (TFEU) Art. 5). Under the principle of conferral, the Union acts only within the limits of the competences conferred upon it in the TFEU.

For the historical analysis of the EU legislation, the authentic EUR-LEX database (***https://eur-lex.europa.eu/homepage.html***) served as the primary source, complemented by a review of relevant works. A quantitative trend analysis, as an independent indicator approach was introduced [11] and applied to other themes [6,12]. This method uses the advanced search functions of EUR-LEX by the *all documents/legal acts,* the given years, and employing the topic-specific phrases, such as *"geolog", "mineral", "hydrocarbon", "energy", "renewable energy", and "geotherm"*.

3. Results

3.1. Historical review

3.1.1. The beginning (1951-1989)

The legislative history of the EU includes a prominent focus on the fossil fuels sector, dating back to the early predecessor, the European Coal and Steel Community. An objective of the Rome Treaty (1951) was "*to promote a policy of using natural resources rationally and avoiding their unconsidered exhaustion.*" The Euratom Treaty (1957) set provisions on raw materials providing a *"common supply policy on the principle of equal access"*. In the 1960-70s, the geology related acquis was limited to resolutions promoting the extractive sector, directives on stocking and trading of uranium and fossil fuels, mines safety, and occupational health. The initial environmental legislation was marked by the Directive on dangerous substances in 1967 (67/548). By the mid-1970s, water policy was established, incorporating the Groundwater Directive. Notably, this directive provides an option to authorise discharges resulting from re-injection of water utilised for geothermal purposes into the same aquifer. Decision 75/51 is the first legislation in the acquis mentioning geothermal energy, and Regulation 729/79 is the first, and only monographic legislation so far, which covers the geothermal sector exclusively. In the 1980s directives on industry accident hazards and environmental impact assessment were adopted. Soil was brought under the purview of the acquis in context of sewage sludge management and plant protection. The Directive on construction affairs (89/106) established requirements for mechanical resistance and stability, paving the way for the development of EU technical standards on geotechnics and seismic design.

3.1.2. Introducing environmental legislation (1990-1999)

In this decade legislation underwent updates on technical safety and occupational health related to drilling, underground mines, and ionising radiation. Aligned with international standards, a statistical system was established for products, such as extracted minerals and semi-finished (intermediary) mineral products. A remarkable milestone occurred in 1994, the Hydrocarbons Directive (94/22), which promoted undistorted open competition in oil and gas exploration and production, also considering geological conditions. Legislation supporting water was developed for urban waste waters, nitrates, and potable water. Additionally, directives on hazardous and packaging waste were introduced. The Landfill Directive (1999/31) addressed numerous geological requirements, including the multi-barrier concept, a stipulation that geological and engineered layers must jointly prevent the migration of pollutants from landfilled waste. The Amsterdam Treaty (1997) introduced a coherent environmental policy by adopting sustainable development through the "*prudent and rational utilisation of natural resources*." In addition to emission- or compartment-specific legislation, a series of "horizontal" laws were introduced, addressing aspects such as free access to information, biodiversity conservation, risk assessment methodologies, integrated pollution prevention and control, and accident hazards prevention.

3.1.3. Extension to the energy and climate sector (2000-2009)

Our century has witnessed significant changes in the acquis concerning geoscientific aspects, both in terms of new topics and the intensity of legislation making, i.e., approximately 50-60 relevant legal documents for each of the last two decades. Due to the Energy Community Treaty (2006) and the Lisbon Treaty (2008), the entire energy sector became subject to the acquis, covering taxation rules, statistics, trade, public procurement, critical infrastructures, gas market, minimum stocks of oil, and the transnational energy grid. The Treaty created an integrated market in natural gas and electricity with a stable regulatory and market framework capable of attracting investment in gas networks, power generation and cross-border transmission networks, providing relevant Parties access to a stable supply. The Renewables Directive (2001/77) set national indicative targets for renewables. Its implementing acts provided specific details on co-generation, including geothermal power plants, energy efficiency, eco-design criteria, ecolabels, and national renewable energy plans. In 2009, its amendment provided a definition for geothermal energy: "*energy stored in the form of heat beneath the surface of solid earth*" without any temperature limitations. The implementing legislation introduced details on geothermal power plants and heat pump requirements and a legal definition of heat pump was created: "*a device or installation that extracts heat at low temperature from air, water or earth and supplies the heat to the building*". The climate dossier, as a new entrant, adopted the international protocols on EU scale. It also introduced measures regarding the geological storage of carbon dioxide, arguably making it the most geology-specific directive in force. Concurrently, in line with decarbonisation efforts, regulations were adopted for the transition of the coal industry.

The waste management law evolved rapidly through essential legislation, including the European Waste Catalogue (2000/532) and related statistics, regulations on discarded batteries, measures regarding packaging waste, classification requirements for landfills and the introduction of a new Waste Framework Directive (2008/98). This directive provided definitions for end-of-waste and by-products, along with recycling targets for construction and demolition waste, offering a potential substitute to natural aggregates. Tailings dam failures (Aznarcollar 1998, Baia Mare 2000; [3]) led to the establishment of legislation on the extractive waste stream, where obligations implicitly require the involvement of professional geologists and include geological aspects. The Water Framework Directive (2000/60) innovated a sophisticated management scheme of river basins and integrated groundwater bodies, mandating hydrogeological studies at all scales. Its subsidiary directives include provisions related to polluting substances, groundwater protection, flood risk assessment, mineral waters, and the marine environment.

The "horizontal" environmental legislation extended to an inventory of emissions (EPRTR), voluntary eco-management schemes, public participation, environmental liability, and registration of chemicals. A significant directive for geologists is the one on spatial information (INSPIRE, 2007/2) encompassing mineral and energy commodity resources and geohazards. Another relevant piece focussed on the eco-labelling of soil improvers and hard floor coverings, playing a pioneering role in introducing resource efficiency considerations and LCA thinking to the acquis. The adaptation of the Kimberley certification scheme for diamonds, and the updated regulations on the safe supply of crude oil and fissile ores were also released. The emerging terror threat led to the publication of a directive on the protection of critical infrastructures.

The Directive on the recognition of professional qualifications (2005/36) and the Regulation on the statistical classification of economic activities (1893/2006) provide a framework for the free movement and profession of geologists within the EU.

3.1.4. Diversification of regulatory fields, non-fuel raw materials as a new entrant (2010-2023)

Over the past 13 years, the acquis has seen a notable diversification of the regulated fields. There has been an ongoing effort to modernise existing regulations through amendments, a push for deregulation, and a campaign advocating for "smart regulation". Alongside these changes, we have witnessed the emergence of new policies, some of which have not attained the same level of legislation, such as non-fuel raw materials, unconventional hydrocarbons, the hydrogen economy, circular economy and open strategic autonomy.

The new energy laws focus on infrastructure, export credits, accounting, research, state aid, concession, procurement, labelling, statistics, internal market rules, resilience, climate change mitigation, and district heating, many of which have explicit citations on geothermal energy. The most remarkable development is on heat pumps covering practically all details. The EU best environmental performance standards for the different sectors now require the consideration of geothermal energy and heat pump supply. The climate package was updated regarding emission accounting, CCS, and risk sectors, along with a decision to facilitate the closure of uncompetitive coal mines. The US shale gas boom did not generate precautionary measures among EU policy makers, despite numerous exploration projects launched in Poland, Hungary, Romania, and the UK. In 2011 France instigated a ban on hydraulic fracturing. The EU Commission and the Parliament published several reports, yet the issue remained at Recommendation level in 2014, covering numerous geological aspects [13]. In addition, a dedicated BREF (Best Available Techniques (BAT) Reference document) was also published.

The environmental dossier underwent amendment with inclusions related to the EIA, Seveso, the Industrial Emissions Directive (2010/75) replacing IPPC, the new Action Programme, and the introduction of new ecolabel standards. The priority in water policy is on the marine environment, thus also covering the extraction of marine minerals. The waste acquis progressed with the ban on mercury, the amendment of the framework directive and landfilling rules and the directive on plastics. Detailed specifications on radioactive waste, end-of-waste, recycling, and ecotoxicity were released. A set of EC decisions were released on the implementation of the Extractive Waste Directive (2006/21).

The last decade brought about the modernisation of the raw materials sector. The OECD conflict minerals initiative was adopted by an EU regulation in 2017. The Raw Materials Initiative in 2008, serving as a potential EU answer to unilateral trade restrictions, launched a set of measures which were major drivers for our professional activities over the last 15 years. Eventually, it became an integral part of the Green Deal, the new growth strategy [14], which aims to transform the EU into a fair and prosperous society with a competitive economy, achieving a state where there are no net emissions of greenhouse gases and economic growth is decoupled from resource use. Geological knowledge requirements are embedded in several key pillars, including clean energy, smart mobility, climate ambition, thus fostering innovation. Raw materials are addressed under "Mobilising industry for a clean and circular economy", signifying that 12% of the materials come from recycling. This calls for actions in resource-intensive industry sectors, waste reduction, and the establishment of a robust and integrated single market for secondary raw materials and by-products. It acknowledges that access to resources is a strategic matter of security. Ensuring a sustainable supply of raw materials, particularly critical raw materials, is necessary for clean technologies and digital, space and defence applications. Diversifying supply from both primary and secondary sources, is one of the pre-requisites for a green transition. As a result of this policy, the draft Critical Raw Materials Act was released on March 16, 2023. Among other recent measures, in response to the COVID crisis and the conflict in Ukraine, Regulation 2021/2106 on the recovery and resilience scoreboard includes several relevant indicators. Additionally, new regulations were published in 2022 on gas storage, including underground storage.

4. Discussion

4.1. Past and present trends

Figure 1. above helps the visualisation of the legal review presented in the previous chapter and highlights some of the major milestones that propelled these trends.

The total number of all (legal and policy) documents increased up to 2014, coinciding with the launch of the smart regulation campaign by the Juncker Commission. The 4-6 years periodicity of negative peaks (e.g., 1989, 1994, 1999, 2004, 2009) reflect the election periods of the Commission and the Parliament. The EU enlargements (1973, 1981, 1986, 1995, 2004, 2007, 2013) have no visible effects on the legislation trend. The number of documents with words "*water*" + *"environment*" show historical correlation with the number of documents with the words "*geology*" + *"soil"* + *"geophys"* + *"mineral*" since the 1990s, the latter having ca. 5-6 times less, 400-700 as compared to 2000-3000 for the previous.

The number of legal documents containing the words *"geology"* + *"soil"* + *"geophys"* + *"mineral"* in the mid-1970s is nearly equal to all documents containing these words, including those with "*water*" + *"environment*". However, their trends begin to diverge in the 1980s. Over the last half-century the number of legal documents with topics explicitly or implicitly relevant to geology has been increasing relative to the overall publication activity of the Community. The legal texts with *"geology"* + *"soil"* + *"geophys"* + *"mineral"* display a curve which peaks in the mid-1970s, with a negative shift in the mid-1990s, and sustained growth since then. On average, over the past half-century, geoscience related documents, broadly speaking, represent about 10 % of the EU's legal documents. Alongside the drivers of policy and legislation illustrated in Figure. 1, it is noteworthy that representative pan-European professional organisations such as EFG, EGS, Euromines, IMA, Eurocoal were established at the turn of the century, engaging in successful lobbying activities.

4.2. Proactive proposal for future legal framework of underground resources

Legislation is commonly a response to social and economic tensions, which can be chronic or acute in nature. The European Parliament, in conjunction with the Council and the Commission, issues annual or biannual legislative priorities aligned with mid-term strategies spanning 4-5 years, such as the Green Deal. These pressures often result from various sources, such as the Court of Justice rulings (e.g., in case of extractive waste), significant public and political turbulence (e.g., hydraulic fracturing, climate change), or international obligations (Kyoto Protocol, responses to the COVID pandemic, or conflict situations). It is relatively less common for scientific research to directly induce new legislation by highlighting existing gaps or contradictions in the law and introducing novel concepts for the legal and regulatory framework.

According to Hámorné et al. [15], the management of underground resources poses challenges due to the emergence of permitting and utilisation conflicts within the underground domain, involving competing resources, such as minerals, geofluids and underground space. These conflicts arise for several reasons. The ownership of these resources is often diverse, being held privately or by the state, and at times ownership can be unclear, such as in the case of determining ownership of multi-level garages. In some instances, ownership is simply not defined by law, for example host rocks or formations accommodating different facilities and activities. The permitting principle is often based on a "first-come-

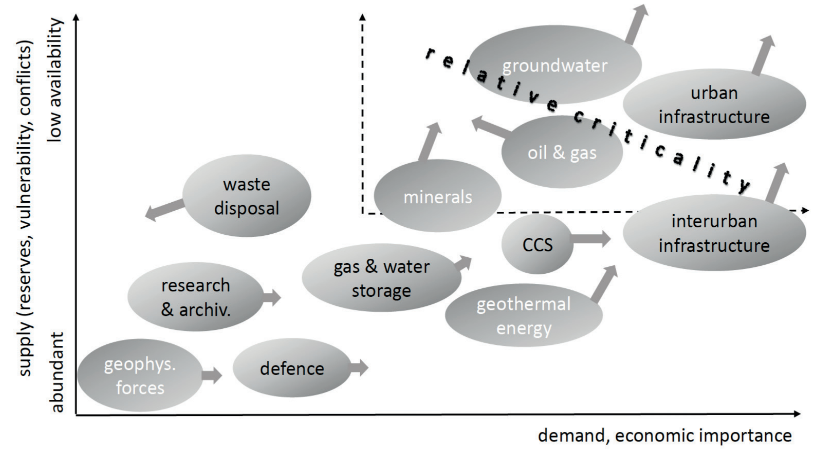

Figure 2: The relative criticality and current trend of underground resources [15].

first-serve" rule, which does not align with the principles of good governance. Moreover, permitting responsibilities are often shared among numerous authorities, some of which lack the required professional competence and knowledge base. The knowledge base itself is often segmented, being managed by different stakeholders like geological surveys, mining inspectorates, utility companies and land use planning-and engineering firms, etc... The economic interests of the state, the regions, the municipality, the investor, and the landowner can differ a lot, leading to long lasting legal disputes. This chaotic situation and the targeted sustainability call for a more systematic assessment toolkit which can promote more harmonised decision making and permitting framework.

The EU legislation has historically faced limitations in this respect. Previously, Member States were opposed to introduce common rules on land use planning, soil and subsoil issues, and on mineral exploration and extraction. Member States historically opposed such rules, viewing them as encroachments on their national sovereignty over governance of their assets. However, this changed a lot in 2023 when the Commission had proposed to draft regulations for both soil and critical minerals. In 2021, Hámorné et al. [15] outlined a set of measures that may pave the way for the sustainable management of underground resources, which includes *(a)* the establishment and upgrade of a national 3D knowledge base, preferably managed by geological surveys and accessible to the public as environmental information; *(b)* develop a robust methodology to perform a comparative criticality assessment on the competing resources (Fig. 2); *(c)* apply the Strategic Impact Assessment Directive in a systematic way, prior to final decision making with regard to these resources; and *(d)* enforce the transition of conventional land use planning into a 3D (4D) spatial development. Given the possibilities presented by the new bills, concerned EU level professional associations, like EFG may consider lobbying efforts to strengthen the role of these professions. This could involve advocating for references in the legal texts that mandate the involvement of chartered geologists in relevant activities, such as signing exploration reports or conducting local underground resources inventories. Needless to say, it is essential that EU level actions must be mirrored by and integrated with measures at the national, regional, and local levels

A few EU Member States already opted for this method. In The Netherlands the new Environment and Planning Act (Omgevingswet) of 2021 combines and simplifies regulations for spatial projects. Dozens of environmental legislations and hundreds of regulations for land use, infrastructure, nature conservation and water were integrated. Citizens and companies can apply for a digital permit at a 'one-stop-shop', whereafter the municipality or province issues the resolution. In Germany, BGR has several projects on the 3D modelling of underground space use and UBA introduced the concept of "potential utilisation zone" as a possible instrument for subsurface spatial planning [16]. In Hungary, the National Science Fund is sponsoring a pilot project led by University of Pécs. This initiative aims to further elaborate into criticality assessment, establish a regional 3D database and outline the requirements for the amending national legislation.

5. Conclusions

Geological themes and resulting duties of geologists are incorporated into several sectoral laws of the European Union. Initially, provisions related to the fossil fuels extractive sector were embedded in the treaties of the European Coal and Steel Community and Euratom. At the end of the twentieth century, environment, water, and waste management was introduced to the Community laws addressing geological aspects. Tailing dam failures occurring at the turn of the century changed this era, the extractive sector became subject to environmental directives. Over the two previous decades, the new energy policy, decarbonisation, the Raw Materials Initiative and the circular economy policy created new mandate for geoscientists. The historical analysis of EU policies and law portray a steady increase in the duties of geologists. The current positive legislation trend favours a proactive initiative for professional lobbying organisations, such as EFG, EGS, Euromines, to promote a harmonised assessment and permitting schemes for all underground resources to ensure a more sustainable utilisation of finite assets through good governance.

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Progress and ambitions of the European Geological Survey Organisations in delivering harmonised subsurface data as the basis for informed energy transition policy

Julie Hollis [1], Francesco Pizzocolo [2], Francesco La Vigna [3], Kris Piessens [4] and Jørgen Tulstrup[5]*

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The Geological Surveys of Europe move steadily toward their ambition to bridge diverse areas where geoscience can support energy transition policy: water, energy, minerals, urban and marine infrastructure, and more. This ambition is built on the European Geological Data Infrastructure (EGDI), which brings together harmonised pan-European subsurface data supported by expert networks. Such efforts tackle the problem that current digital twins of the Earth largely ignore important subsurface resources and processes. We demonstrate how subsurface data supports implementation of Green Deal policy through case studies at national, municipal, and EU level. These cases also allow looking from the past toward the future and underline the importance of dedicated community efforts to build EGDI and a Geological Service for Europe.

Les Services géologiques d'Europe progressent progressivement vers leur ambition de relier divers domaines dans lesquels les géosciences peuvent soutenir la politique de transition énergétique : l'eau, l'énergie, les minéraux, les infrastructures urbaines et marines, et bien plus encore. Cette ambition s'appuie sur l'Infrastructure européenne de données géologiques (EGDI), qui rassemble des données souterraines paneuropéennes harmonisées soutenues par des réseaux d'experts. De tels efforts s'attaquent au problème selon lequel les jumeaux numériques actuels de la Terre ignorent largement d'importants ressources et processus souterrains. Nous démontrons comment les données souterraines soutiennent la mise en œuvre de la politique du Green Deal à travers des études de cas aux niveaux national, municipal et européen. Ces cas permettent également de regarder du passé vers l'avenir et soulignent l'importance des efforts communautaires dédiés pour construire l'EGDI et un service géologique pour l'Europe.

Los Servicios Geológicos de Europa avanzan constantemente hacia su ambición de unir diversas áreas donde la geociencia puede respaldar las políticas de transición energética: agua, energía, minerales, infraestructura urbana y marina, entre otras. Esta ambición se basa en la Infraestructura de Datos Geológicos Europeos (EGDI, por sus siglas en inglés), que reúne datos armonizados del subsuelo pan-europeo, respaldados por redes de expertos. Estos esfuerzos abordan el problema de que las representaciones digitales actuales de la Tierra, ignoran en gran medida, importantes recursos y procesos del subsuelo. Demostramos cómo los datos del subsuelo respaldan la implementación de políticas del Pacto Verde a través de estudios de caso a nivel nacional, municipal y de la Unión Europea. Estos casos también permiten mirar desde el pasado hacia el futuro y subrayan la importancia de los esfuerzos comunitarios dedicados para construir EGDI y un Servicio Geológico para Europa.

1. Introduction

Science-informed policy is a goal to which both scientists and politicians aspire. However, achieving this goal requires overcoming multiple challenges from both the science and policy realms. These challenges include availability of: high-quality, up-to-date, harmonised data; expert advisory services; effective translation of scientific information, risk and uncertainty information in non-technical language; timely action; policy-suitable formats and tools; and strong networks and relationships [e.g., 1]. Overcoming these challenges in applying geoscience to policy is the driver for the strategic ambition of the European National Geological Survey Organisations (NGSOs) to establish a sustainable Geological Service for Europe.

Through their collaboration via EuroGeoSurveys the NGSOs have worked already for many years toward establishing the envisaged Geological Service for Europe. Recognising that high-quality harmonised data on the subsurface was essential to supporting implementation of EU policy. EuroGeoSurveys established the European Geological Data Infrastructure (EGDI) in 2016 as the framework for geoscience data, information, and knowledge across the broad spectrum of geoscientific thematic areas relevant to policy: minerals, energy, groundwater, hazards, urban development, coastal zone management, offshore

[1] EuroGeoSurveys
[2] Geological Survey of the Netherlands, TNO
[3] Geological Survey of Italy, ISPRA
[4] Geological Survey of Belgium
[5] Geological Survey of Denmark and Greenland,
[*] julie.hollis@eurogeosurveys.org

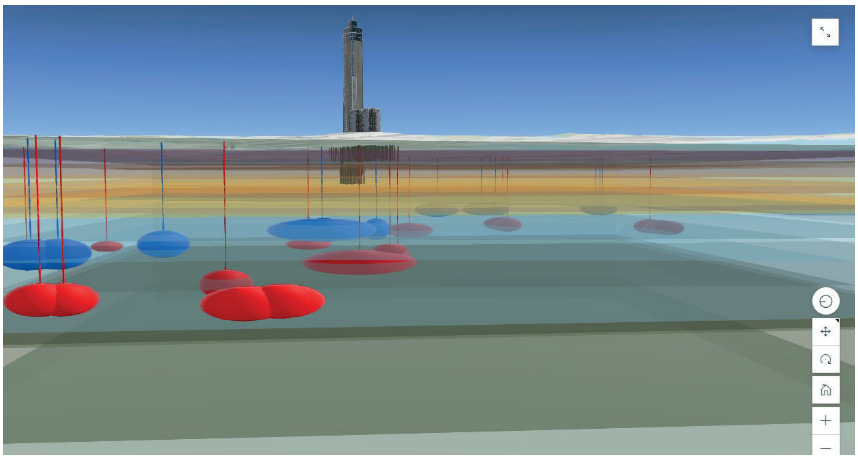


Figure 1: Simplified visualisation of the spheres of influence of heat and cold storage in the subsurface beneath the Zalmhaventoren, from https://storymaps.arcgis.com/stories/c872fa2b6d504ded8dcd29a8f819ca58.

infrastructure development, carbon and hydrogen storage potential, soil chemistry, and the geological maps and models fundamental to understanding all of these areas. EGDI development was ramped up through GeoERA, an ERA-NET co-fund program that delivered a wealth of new, harmonised geoscientific data to understand the European subsurface and inform policy in the areas of geo-energy, groundwater, raw materials, and further development of the information platform (EGDI). This is continued in the current Geological Service for Europe (GSEU) project, a 5-year HE-funded Coordination and Support Action project, with the ultimate goal of establishing a sustainable Geological Service for Europe that will continue to provide these geoscientific services to support policy into the future.

The ambitions of the NGSOs and EuroGeoSurveys are paralleled by policy developments in Europe over the past decade that increasingly require a dedicated geological service. Multiple EU policy spheres requiring data and knowledge of, e.g., soils, groundwater, energy, minerals, hazards, and space have converged and culminated in the European New Green Deal [2–7], with increased coordination between Directorate Generals of the European Commission. Historically limited recognition, amongst policymakers and general publics, of the key role that knowledge of the subsurface plays in effective implementation of these policies seems to be changing, at least partly because of projects like GeoERA and GSEU, and the ongoing representation of EuroGeoSurveys experts on EU expert advisory boards and panels. A highpoint of this process is that in 2023 – for the first time – the geological surveys of Europe are recognised by name in the EU Critical Raw Materials (CRM) Act [3] regarding their role in delivering harmonised data and expert advice to boost knowledge of Europe's CRM potential.

In this contribution, we present three short case studies involving EuroGeoSurveys and its member NGSOs that highlight the application of geoscience to policymaking at municipal, national, and EU level, looking from the past, through the present, to the future. All three rely on delivery of high-quality, FAIR, harmonised data and expert advice, including through EGDI – a core element of a Geological Service for Europe.

2. An established national geoscientific data repository to support policy: the Dutch key register for the subsurface

In September 2015, the Dutch Parliament endorsed the Basic Subsurface Registration Act (BRO), a legislative framework for establishing a unified, digital, and detailed repository of soil and subsurface data. The Act aimed to dramatically improve management of the Dutch subsurface by centralising the collation of subsurface data and validating, harmonising, and democratising these data, thus preventing avoidable excavation mishaps, elevated costs, hazards for workers and residents, and construction delays due to flawed, inadequate, or inaccessible data. Previously, the responsibility for subsurface data was dispersed among various organisations. TNO is now the centre responsible for the BRO's implementation and operational management.

The BRO's database was progressively expanded, starting in 2018 from groundwater and geotechnical drillings, to later include soil samples, geophysical measurements, geological descriptions, and groundwater measurements. During 2024, the final phase will involve expansion to include environmental and contamination data.

In addition to the original goal of preventing costs and mishaps, the added value of national data centralisation and harmonisation afforded by BRO has already become evident through the case of the Zalmhaventoren in Rotterdam, which exemplifies how geoscientific analysis and visualisation can surmount complex subsurface challenges, in this case the impact of the Maas River on groundwater dynamics.

In 2018, the monumental Zalmhaven Tower project commenced – a trio of interconnected residential skyscrapers in Rotterdam's heart, encompassing a total area of 15,541 m². Throughout the tower's design and construction, understanding the soil and subsurface emerged as key to energy systems, foundations, pre-existing underground elements, and overall infrastructure. The project brought together commercial entities, local municipalities, and national government bodies, united in collaborative spatial planning, management, and oversight of the urban landscape. The project also integrated diverse data standards for GIS (cityGML, I3S, SGY, XML), BIM (IFC, AutoCad), and other 3D data (such as OBJ) from disparate domains, requiring an intricate fusion of technologies.

A notable aspiration for the Zalmhaventoren was to harness subsurface energy for the heating and cooling of the complex via heat and cold storage in underlying aquifers. This was possible using 3D visualisation via the BRO's REGISII model. REGIS II is a comprehensive 3D model, through which it is possible to visualise the Dutch subsurface to approximately 500m depth and in 100 x 100m blocks, including hydrogeologic units, allowing recognition of permeable and less permeable strata. These hydrogeologic units have relatively uniform hydraulic properties, allowing nuanced analyses, and are also harmonised with, or integral to, the lithostratigraphic units identified in the Digital Geological Map (DGM). The model delivers permeability data for nearly every unit, allowing effective decision-making regarding groundwater management and providing a basis for further hydrogeological investigations. The model also forms the foundational framework for developing national and regional groundwater

GEOLOGICAL SURVEY OF ITALY

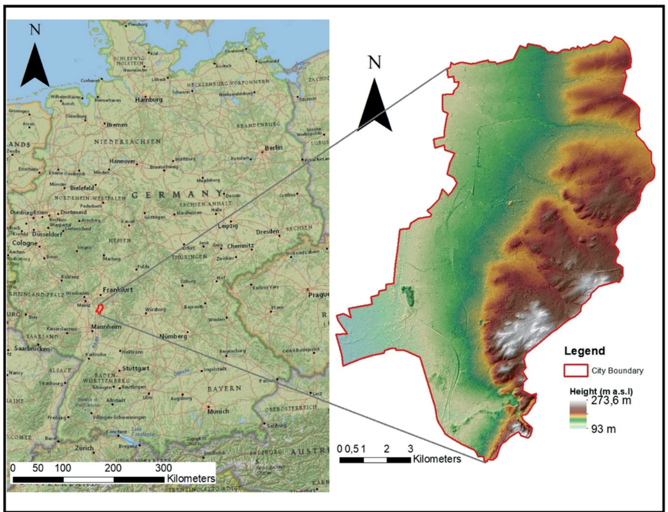
URBAN GEO-CLIMATE FOOTPRINT

GEO FACTSHEET OF THE CITY OF Darmstadt

City analysis provided by HLNUG – Für eine lebenswerte Zukunft

General city info

The city of Darmstadt is located in southwestern Germany, 30 km south of Frankfurt am Main in the infrastructurally well-developed Frankfurt/Rhine-Main metropolitan region. The exact geographic location of the city, in relation to the centrally located tower of the city church, is given as 49.8728253 north latitude and 8.6511929 east longitude. The city has an area of 122 km² and stretches 15 km in west-east direction and 17 km in north-south direction. It is home to 162428 inhabitants, which corresponds to a population density of 1329 per km².



Location of Darmstadt and its morphology (sources: ESRI Basemap, HVBG 2017)

City data

City data	
Area km²	122
Inhabitants	162,428
Pop.Density (inh/km²)	1,329
Average Elev. m asl	144
Lat. (WGS84)	49.8728253
Lon. (WGS84)	8.6511929
Administrative level	Municip./LAU
Clim. zone Köppen-Geiger	Cfb
UNESCO SITE	Not
Germany	

Type of groundwater-city	Groundwater city type 1
0	
0	

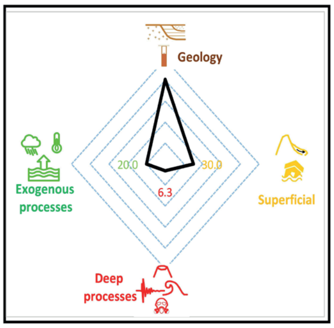
UGF - Classification

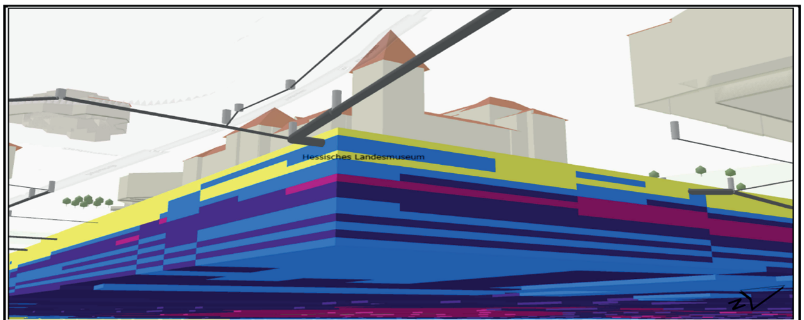
Geology dominated

Superf. processes dominated

Geological setting descriprion

The Upper Rhine Graben (URG) is a Cenozoic sedimentary basin formed during the Alpine Orogenesis since about 37 Ma BP. The URG is bounded by NNE-SSW trending major faults and contains many minor faults, forming distinct depositional centers within the URG (Pflug, 1982; Schumacher, 2002; Behrmann *et al.*, 2005). The eastern master fault of the URG has a displacement of at least 1,500 m. Geologically, the city of Darmstadt lies partly within the URG and partly on its eastern flank. Thus, the western part is flat and underlain by deposits of the Rhine; while the eastern part, located on the Odenwald mountains, is dominated by a rugged topography with some steep slopes. Geologically, the city area is described on the basis of the sheet section with 4 geological maps at a scale of 1:25,000. Furthermore, there are about 1800 boreholes, which reach a maximum depth of about 130 m. Thereby the content detail and load capacity of the drillings is very heterogeneous. For this reason, and because of the complexity of the bedding conditions, the development of a stratigraphic 3D model is currently not possible. Therefore, the focus is on the development of parameter models. Tectonic faults pose a particular challenge. Numerous small faults in the graben area are postulated but have not been located and verified. In conjunction with the possible migration of radon along such structures, this creates a geohazard that cannot be extensively quantified. Current work is attempting to adequately address this issue using, among other things, shear wave seismic. In addition to the usual interventions, the near-surface subsurface has also been anthropogenically influenced by the creation of cavities that were used for ice storage in earlier times.



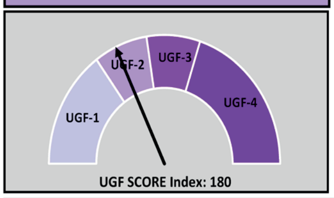


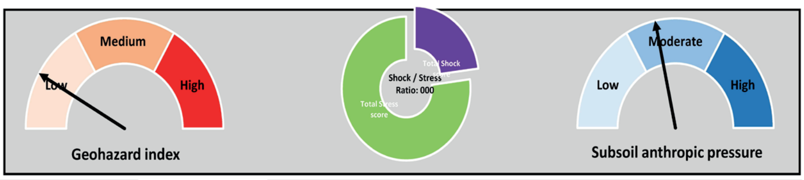
Subsurface of Darmstadt city showing geological voxel model and sewage system

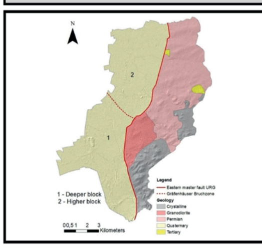
UGF SCORE INDEX	180

UGF SCORE CLASS DESCRIPTION

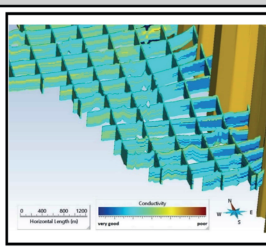
UGF-2 - Moderate impact of geological setting/phenomena interfering with the geographical location of the human settlements, with several geological issues in some areas or widely. Knowledge and awareness of urban geology and climate change effects are crucial for urban planners and managers.







Northern portions of the URG within Darmstadt have up to 1,800 m of Tertiary and Quaternary sediments. The Odenwald mountains forming the eastern flank of the URG consist of granodiorite and other crystalline rocks in the southeast and Permian sandstones, claystones, and volcanic rocks in the north. Sediments are separated from the Odenwald mountains by the acitve eastern master fault of the URG. This fault also is controlling the morphology of the area.



The granodiorite typically has very thick weathered zones with extensive granular disintegration. Eroded weathered rock and soil from the slopes in this hilly terrain are deposited within the URG, where they are inter-bedded with alluvial basin-fill deposits. Granodiorite and dislocated weathering products are rich in uranium and thorium, which are the mother nuclides for radon. In several parts of the city increased indoor radon concentrations are given, also because

Geoheritage

Indicator of n. of geosites (to be developed)	Geoheritage picture	Geoheritage description

Tool version 7.31

Figure 2: Geofactsheet of the city of Darmstadt, produced from the Urban GeoFootprint project.

models, affording a holistic understanding of hydrogeological dynamics.

3. A current application of geoscience to policy at municipality level: the Urban Geo-climate Footprint project

According to the United Nations [8], cities will soon be places where more than half the world's population will live. Thus, improving the resilience of cities is a crucial theme of the agendas of governments and NGOs. The first action to increase resilience of cities is to work on the awareness of their inhabitants and decision makers about all possible hazards and problems present in the city area, but also to engage citizens in this process through dissemination instruments and activities [9]. Here, geology plays an important role.

Cities are in constant interaction with their geological settings, but these characteristics are often hidden and thus "out of sight, out of mind" for citizens and decision makers. The Urban Geo-Climate Footprint (UGF) project [10,11], designed within the framework of the Urban Geology Expert Group of EuroGeoSurveys, is the first example of holistic preliminary analysis of the geological and subsoil-related climate effects on urban areas due to local geological setting, deep processes, superficial processes, exogenous processes, and subsoil anthropic pressure. The aim of the UGF was to develop and share a tool capable of producing a holistic representation of all geological and subsoil-related climate effects on the city. Data taken from available repositories (e.g., the Global Seismic hazard map) were indexed and translated into scores and combined to reach a total value for the analysed city.

The basic assumption of the UGF project is that cities with similar geological-geographical settings have similar challenges to manage, both due to common geological problems and climate change effects on the surface and on the subsurface. The UGF tool produces a useful and user-friendly result consisting of a semi-automatic "city geo-factsheet" (Figure 2) specific to the city considered and defines the so called "UGF score Index", which is a quantification of its geological complexity. This allows for a direct city-to-city comparison and best practices exchange, but also to raise awareness of inhabitants and decision makers of the geological setting and the link to climate phenomena that persists in urban areas. The tool is currently designed and applied only at European level, but in the near future it will be globally available, allowing for the indexing and clustering of cities worldwide.

4. A future application of geoscience to policy at EU level: the Critical Raw Materials Act

Recent EU legislative action to boost resilience in the raw materials supply chain has its origins in the 2008 Raw Materials Initiative. Since then, the EU has only increased legislative developments related to the role of raw materials in the green transition, involving policy that increasingly intersects under the banner of the European Green New Deal [e.g., 2, 3, 7, 12–19] and initiatives such as the Global Gateway and InvestEU. These legislative actions are consequences of the recognition of Europe's current weak supply chain position, further exposed by the ongoing impacts on the EU energy sector of the war on Ukraine [e.g., 20–22]. This has driven an acceleration of the EU ambitions to boost energy resilience via the REPower EU Plan [17], which specifically identified the key role of critical raw materials (e.g., lithium, cobalt, and rare earth elements) required for renewable energy technologies.

Now, for the first time, the European NGSOs are named in EU legislation as part of the CRM Act [3], a key recognition of the role of geoscience in EU-funded raw materials projects (e.g., ProSUM, Minerals4EU, MICA, ORAMA, the EU Latin America Partnership on Raw Materials, SCRREEN, GeoERA, Futuram, EIS, GSEU) and other initiatives. Under Article 35 of the Act, "a subgroup bringing together national geological institutes or surveys" will contribute "to the coordination of national exploration programmes…" This requirement to deliver national data and expertise at EU level, following UNFC standards, and building on existing collaborative efforts of the NGSOs and EuroGeoSurveys through, e.g., GSEU – particularly if supported by a future Geological Service for Europe and EGDI – will enhance the EU's prospects for boosting resilience in domestic raw materials supply.

5. Conclusions

The complexity of human-Earth interactions that impact the climate crisis – e.g., human impacts on soil quality, groundwater quality and quantity, coastal zone stability, CO_2 emissions, and competing subsurface uses for resource extraction and storage – require that climate-relevant policy is firmly grounded in sound geoscientific advice based on up-to-date, high-quality subsurface data and expertise. The urgency to tap into the subsurface's clean energy potential is only increasing. The three case studies presented here, at municipality (Urban geo-Climate Footprint), national (Dutch BRO), and EU level (Critical Raw Materials Act), demonstrate the evidence for major improvements in sustainable use and management of the European subsurface through the application of subsurface data and knowledge to policy implementation. The three cases also demonstrate key aspects that must be incorporated into future, necessarily more ambitious, initiatives to harness subsurface data and knowledge to achieve the energy transition, namely: a legislative framework for subsurface data management (e.g., BRO), delivery of national geoscience data, harmonized at EU level (e.g., the CRM Act), and building collaboration between the geoscientific community and public administration (e.g., the UGF project). Such actions can drive the delivery of high-quality, harmonised subsurface data, information, and knowledge effectively into the policy-making sphere [e.g., 17]. The link to a foundational FAIR 3D subsurface data infrastructure, such as EGDI is clear.

To some degree, this need is already recognised at EU and national levels. For example, via Digital Europe, the EU has invested in the Green Deal Data Space, to support the European Green Deal. The Green Deal Data Space will be an infrastructure that supports open data sharing from multidisciplinary providers and initiatives, including geoscientific data. Also supported by Digital Europe is the Destination Earth initiative, which aims to build highly accurate digital twins, or models, to monitor and simulate natural phenomena, hazards, and related human activities. While focusing initially on weather and climate change, future components of the digital twins (to be developed post-2024) will incorporate geophysical data.

6. Future pathways

The ultimate ambition of a full digital replica of the Earth, as envisaged by 2030, must necessarily incorporate geoscientific data types not yet planned for. This is indicative of the still large gap that geoscience must cross to effectively inform policy. For example, the current EU Urban Agenda focusses on themes including climate adaptation, energy transition, and sustainable use of land and nature-based solutions but there is no policy recognition of the key role that sustainable management of the urban subsurface will play in all of these areas, e.g., management of urban groundwater, subsidence, geothermal energy, or urban underground storage space (for infrastructure, fuel, heat and cold).

The need for sound geoscience to inform policy is, however, widely recognised within the geoscientific community. The success of the Dutch key register and the EU vision of digital transformation, allow for a vision of a future EU multi-scale 3/4D key register/data infrastructure, a further developed EGDI. Such a 3/4D data infrastructure could support modelling of different datasets that represent features and processes that interact in the Earth's subsurface (e.g., groundwater, heat, faults, pore space, etc). This would necessarily require application of machine learning technologies to handle the extremely complex 3D and 4D modelling required for predictive modelling of multiple subsurface datasets and data types, and could greatly enhance our ability to sustainably use and manage the European subsurface. The heterogeneous distribution of non-harmonised data across Europe needs to be tackled, but local and in some cases regional models are already within reach and have proven value. An absolute requirement is – as in the Dutch case – allowing reuse of subsurface data. This ongoing journey toward the delivery of increasingly advanced, harmonised 3D and 4D data through open access portals perhaps best captures the direction of travel for collaborative European geoscience for society.

Conflicts of Interest: The authors declare no conflict of interest.

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Communicating geothermal geoscience results to improve public policies and social acceptance of geothermal energy

*Dario Bonciani [1, *], Amel Barich [2], Marco Vichi [1], Alice Pippucci [1] and Loredana Torsello [1]*

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Geosciences applied to the exploitation of geothermal resources have achieved significant scientific progress. The adoption of geothermal research results in public policies can contribute to meet the challenges set by EU Strategies. Geoscientists are facing challenges to communicate scientific results to stakeholders. There are many studies on geothermal that are ignored by policies and public actions, hindering promising chances of including geothermal energy as an important player in the ongoing energy transition. This is partly due to difficulties in communicating geoscientific content efficiently to non-technical audiences. The article aims to analyse past experiences, current practices, and future opportunities to better communicate scientific results as a means to better support policy making and highlight the role of geoscience in achieving sustainability goals.

Les géosciences appliquées à l'exploitation des ressources géothermiques ont réalisé des progrès scientifiques importants. L'adoption des résultats de la recherche géothermique dans les politiques publiques peut contribuer à relever les défis posés par les stratégies de l'UE. Les géoscientifiques sont confrontés à des défis pour communiquer les résultats scientifiques aux parties prenantes. De nombreuses études sur la géothermie sont ignorées par les politiques et les actions publiques, ce qui entrave les chances prometteuses d'inclure l'énergie géothermique en tant qu'acteur important dans la transition énergétique en cours. Cela est dû en partie aux difficultés rencontrées pour communiquer efficacement le contenu géoscientifique à un public non spécialisé. L'article vise à analyser les retours d'expériences, les pratiques actuelles et les opportunités futures pour mieux communiquer les résultats scientifiques afin de mieux soutenir l'élaboration des politiques et mettre en évidence le rôle des géosciences dans la réalisation des objectifs de développement durable.

Las Ciencias de la Tierra aplicadas a la explotación de recursos geotérmicos han logrado avances científicos significativos. La adopción de los resultados de investigaciones geotérmicas en las políticas públicas puede contribuir a cumplir con los desafíos establecidos por las Estrategias de la UE. Los geocientíficos enfrentan desafíos para comunicar resultados científicos a las partes interesadas. Hay muchos estudios sobre geotermia que son ignorados por las políticas y acciones públicas, obstaculizando las prometedoras oportunidades de incluir la energía geotérmica como un actor importante en la transición energética en curso. Esto se debe en parte a las dificultades para comunicar de manera eficiente el contenido geocientífico a audiencias no técnicas. El artículo tiene como objetivo analizar experiencias pasadas, prácticas actuales y futuras oportunidades para comunicar mejor los resultados científicos como medio para respaldar mejor la toma de decisiones políticas y destacar el papel de la geociencia en el logro de objetivos de sostenibilidad.

1. Introduction

Geothermal is a renewable, reliable, versatile and stable source of heat and electricity, with a high-capacity factor and low levelised cost of energy [1].

[1] Consortium for the Development of Geothermal Areas (COSVIG)
[2] GEORG - Geothermal Research Cluster
[*] d.bonciani@cosvig.it

It can play an important role in decarbonising the energy mix, which emits 75% of EU (European Union) greenhouse gases. Geothermal is a strategic resource to achieve the Paris Agreement targets, to keep global warming within safe levels aligning with the European policies for green transition and full decarbonisation by 2050. This includes the European Green Deal and Fit for 55 packages [2]. Geothermal heat can decarbonise 25% of the EU energy needs [3], while fluids will provide raw materials.

Despite this and although the European Union Strategy for Solar Energy (COM(2021) 221 final) states a target to triple the geothermal capacity by 2030, dedicated measures to achieve a significant deployment of geothermal energy are lacking [4, 5, 6, 7]. Low visibility, citizen engagement and minimal impact in policymaking affect geothermal, comparable to challenges faced by

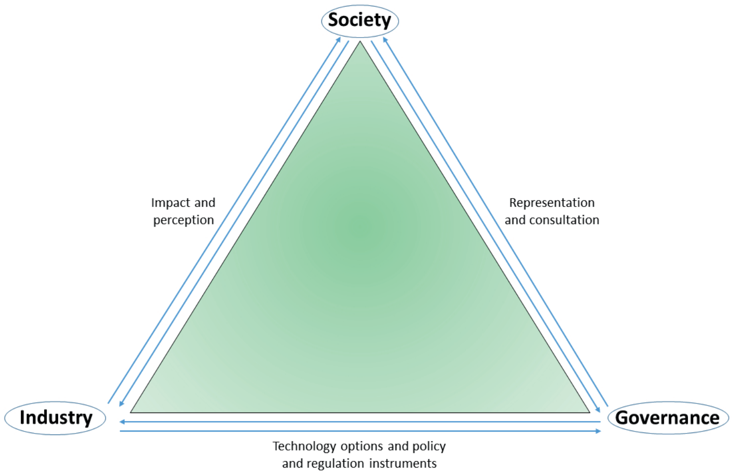

Figure 1: Connections between society, industry and governance.

other geosciences [8]. Although used for thousands of years, geothermal is considered an emerging technology [10, 11] with low awareness of its potential [12]. The lack of familiarity leads to confuse different technologies, such as deep and shallow geothermal systems, or petrothermal and hydrothermal deep geothermal projects. These misunderstandings and difficulties in communicating complex technical information may result in unfounded public resistance [13, 9]. Sub-surface technologies are perceived out of sight and out of mind; an unfamiliar realm and a source of concerns [14, 15]. The scientific community often pays less attention to communicating with the public and may find difficulties to adapt contents and disseminate results through non-scientific media. Many earth scientists believe that their research is not acknowledged by policies and have a limited understanding of the policy-making processes [8, 16].

Technology, society and governance interact closely; communication about the environment and energy technologies shapes the public opinion and changes policies (Figure 1; [17]). It is important that information is shared effectively, to avoid disputes and encourage adequate policies.

Echoes of the social conflicts on geothermal in Monte Amiata (Italy) reached the national Government and the European Parliament [18], while opponents to a project in the Canton of Jura (Switzerland) collected signatures to call for a vote to ban deep geothermal [10].

Communication should become part of the geoscientists' activities and reliable information on the underground may contribute to decision-making. Surveys in Italy [18, 12] reported preferences of local communities to receive information from researchers and local scientists, instead of administrators and companies [11]. This trust in scientists encourages a dialogue between experts and non-experts [19].

The geoscience information translation into the public and policy sphere requires deep understanding of how people receive, perceive and process information and interaction with communication experts. Participatory engagement and dialogue are effective communication strategies [14]. Books, brochures, maps and the virtual reality can support geoscience communication and education [8]. Traditional mass media (newspapers and TV) target a substantial segment of the population [20], although they tend to exaggerate positions in the geothermal debate [21] and in some cases are considered not impartial. The internet [11] or social media are preferred, despite the risk of extreme simplifications. Alternative ways to educate on geothermal is through geotourism [22].

Next chapters provide examples of geothermal science communication to citizens and policymakers involving authors and institutions, at both international and national levels, in two of the main "geothermal countries": Italy and Iceland. Grounding on these experiences, recommendations on how to report geoscience results to a non-technical audience will be provided, with the objective to help promote effective communication on geothermal.

This research is part of the social engagement and communication preparatory work to be implemented within the COMPASS Project [23], aimed at proposing sustainable and cost-efficient solutions for managing geothermal wells in supercritical contexts.

2. Materials and Methods

This study aims to investigate effective communication strategies for conveying complex geoscience findings, particularly in the context of geothermal energy, to non-expert audiences, including policymakers and citizens. The research methodology commenced with an extensive literature review, focusing on communication initiatives and key publications. Special attention was given to initiatives in which the authors were directly involved, such as EU-funded projects, including GEOENVI [24], GECO [25], DEEPEGS [26], GEOTHERMICA [27], and CROWDTHERMAL [28].

Additionally, the review considered local and national experiences, with the authors' participation, including communication efforts in Italian geothermal regions, initiatives to engage high-level policymakers in Italy, and communication campaigns in and from Iceland, such as #GeothermalFriday and #LetsTalkGeothermal.

The analysis encompassed various facets of communication strategies tailored to different non-expert target groups, namely policymakers and citizens. Key aspects under examination included the objectives of these communication efforts (e.g., awareness raising, policy advocacy, addressing environmental and safety concerns, facilitating project decision-making, education, and event chronicling), the diverse communication channels employed (e.g., newsletters, newspaper articles, websites, social media, videos, seminars, public events, meetings, factsheets, and position papers), the choice of language used, and the core messages conveyed.

The results derived from this comprehensive analysis have culminated in a set of recommendations for geoscientists seeking to effectively communicate their research outcomes to non-expert audiences, ultimately aiming to enhance awareness, foster social acceptance, and influence policy decisions in support of sustainable geothermal energy utilisation.

3. Background analysis

Efforts have been put in place to communicate geothermal to policymakers, with the final aim of facilitating policies to increase its deployment. Sector organisations, public bodies and informal clusters interested in geothermal development publish informative volumes, policy briefs and factsheets or position papers. They organise events and bilateral meetings or send emails to relevant policymakers. Earth scientists and technicians usually provide scientific basis to these messages and initiatives. Citizens and local communities, but also policymakers, are reached by different kind of communication tools which contribute to raise their awareness and inform them about scientific advancements.

Actions directly financed by the EU pay importance to communication activities tailored to different groups of stakeholders, including non-technical public consisting of policymakers and citizens. These activities are usually also aimed at improving social acceptance and promoting policies on geothermal energy.

The following subchapters report a review of all experiences where the authors' organisations were directly involved.

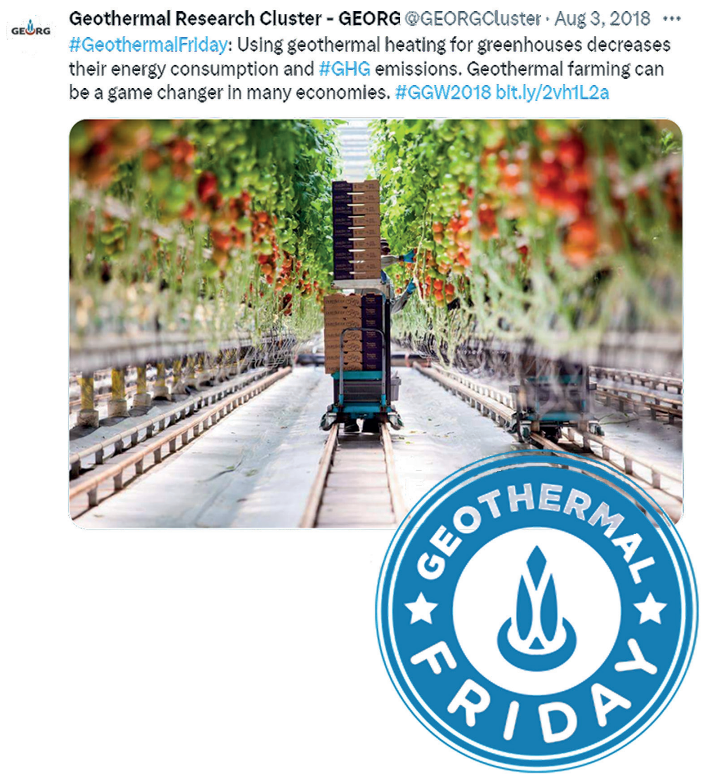

Figure 2: #GeothermalFriday Outreach Initiative by GEORG – Geothermal Research Cluster.

3.1. Geoscience communication in EU funded geothermal energy projects

Within the framework of science and technology funding initiatives, the EU has recognised the significance of effective communication as an integral component of its funding criteria. EU guidelines emphasise that communicating research, development, and innovation projects should transcend mere reporting of project activities; it should encompass the explanation of the underlying science and the processes involved [29]. Communication strategies within EU-funded projects entail specialised efforts that converge to bridge the gap between intricate scientific concepts and methodologies and public comprehension. These bridges are essential for cultivating trust and ensuring the sustainability and adoption of the solutions and knowledge being developed.

As an emerging industry, geothermal energy is still establishing its reputation and role within the broader renewable energy landscape and the EU's energy transition agenda. Due to its context-dependent development process, geothermal energy heavily relies on geoscience, particularly subsurface knowledge, to assess its utilisation potential and environmental impact. Geoscience communication strategies within EU geothermal projects employ diverse approaches tailored to each initiative's requirements and scope. Typically, an educational component is incorporated to raise awareness about the project's objectives.

For projects such as GEOENVI and Geothermal Emission Control (GECO), which respectively address deep geothermal environmental impacts and carbon capture, storage, and utilisation within geothermal energy, social media campaigns and webinars have played a pivotal role in disseminating knowledge regarding the methodologies employed to assess and mitigate geothermal energy's environmental impacts. In GEOENVI, a combination of national and EU-level seminars, coupled with targeted communication campaigns, facilitated discussions on project outcomes. An Environmental Database on the project's website provided comprehensive information on environmental effects. Furthermore, weekly updates on technical subjects were shared on the project website and social media platforms, accompanied by the hashtags #GEOENVI and #ThisWeekGoodNews. GEORG has sim-

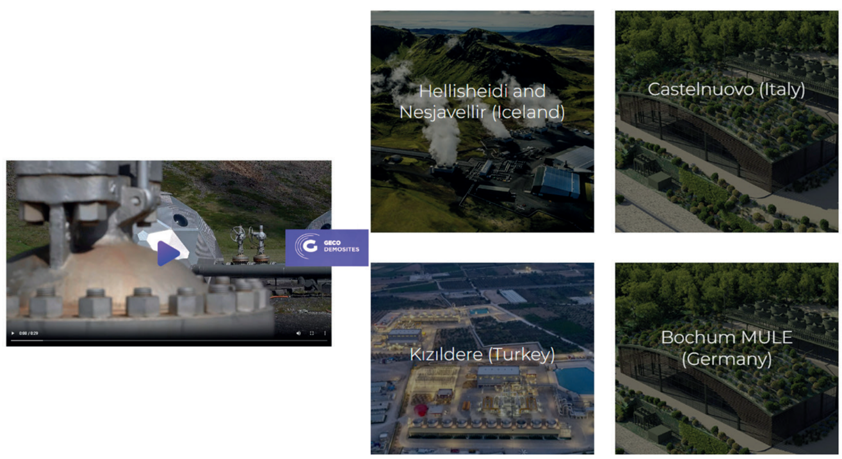

Figure 3: Geothermal Emission Control (GECO) Project's online permanent exhibition of its demonstration sites.

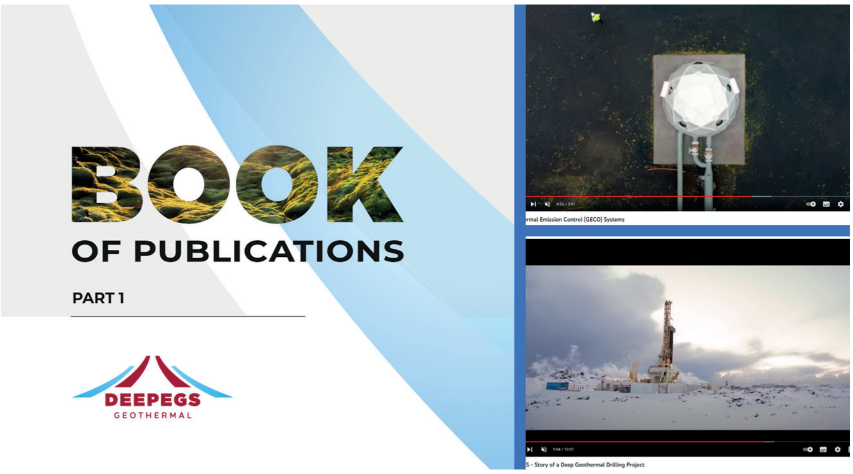

Figure 4: (a) DEEPEGS Book of Publications; (b) GECO and DEEPEGS Mini documentaries.

ilar initiatives called #GeothermalFriday and #LetsTalkGeothermal (Figure 2).

Overall, the strategy aimed to increase awareness, harmonise regulations, and garner support for deep geothermal projects across Europe. In the case of GECO, which focused on testing the Carbfix solution [30] across diverse geological settings in Europe, an online permanent exhibition was created to showcase its four demonstration sites (Figure 3). This exhibition detailed the science and technology developed throughout the project's duration. Additionally, in-person workshops and summer schools were integral components of GECO's knowledge dissemination plan. Moreover, project deliverables were simplified into factsheets to facilitate result communication.

On the other hand, DEEPEGS, a project centered on deep drilling and enhanced geothermal systems, prioritised high visibility through EU communication platforms such as HORIZON 2020 EU Research & Innovation Magazine and Euronews Futuris TV. These platforms were leveraged to convey the project's ambitious scope. Furthermore, DEEPEGS compiled its scientific results into a publication, which was made available to project partners and stakeholders (Figure 4).

Traditionally, science communication has been associated with written press formats. However, recognising the evolving media landscape, audio-visual resources have gained prominence in science communication. Both DEEPEGS and GECO produced videos in the form of interviews or short documentaries (Figure 4) to succinctly summarise their project scopes and results, aiming for a broader impact. This shift towards audio-visual materials aligns with the increasing consumption of this content by the public in recent years.

3.2. Communicating geothermal science to policymakers

The authors' entities are actively involved in activities to communicate geothermal to policymakers. The Italian Piattaforma Geotermia (Geothermal Platform) is a permanent group of entities and associations dealing with geothermal energy. This platform operates under the coordination of the national professional association of geologists and focuses on advancing the deployment of geothermal heat pumps and direct applications. It achieves this goal through proposals aimed at simplifying authorisation processes and formulating appropriate policies for incentives and information dissemination. The initiative acts through meetings and collaborations with relevant policymakers and is punctuated by press releases to emphasise the role of geothermal energy. Additionally, high-profile events, such as a conference held in Rome in June 2022, featuring the Italian Minister for Ecological Transition as one of the keynote speakers (Figure 5), served to communicate the importance of geothermal energy and its opportunities to a diverse audience. Similar events were organised by the Platform in October 2022, involving Region of Tuscany, geothermal territories, companies, and geoscientists. In March 2023, through a collaboration with the Italian Geothermal Union and the National Research Council.

To increase the awareness of opportunities offered by geothermal and communicate on technical topics related to this renewable energy, notably geological aspects, potential environmental and health impacts, their monitoring and mitigations COSVIG organised a round of non-technical seminars for its member mayors, with presentations from geoscientists and scientific journalists. At general EU level, projects like GEOTHERMICA and GEOENVI have touched upon direct communication with policy makers through initiatives like JoProShow, a map-based tool to promote geothermal in Europe, and policy briefs, respectively.

3.3. Communicating geothermal science to the civil society

COSVIG has managed the communication on geothermal energy for more than 10 years, publishing the weekly newsletter *GeotermiaNews*, to inform politicians and citizens in the geothermal areas of Tuscany (Italy) and to foster greater social acceptance of geothermal energy by local communities. This initiative was launched after agreements between geothermal operators of powerplants in Italy and regional and local authorities that identified COSVIG as an impartial body in charge for the institutional communication on geothermal. Articles were mainly on innovative advancements in earth sciences and geothermal technologies, events, socioeconomical benefits linked to geothermal energy, results of studies on potential environmental and health impacts, concerns and barriers. In this framework, COSVIG collaborated with a local television (TV9 Italia) to produce GEOLINK, a monthly in-depth column on geothermal areas, consisting of six episodes to raise awareness of geothermal regions, including geothermal innovation initiatives. Concerning a more specific communication on geothermal energy aspects at national level, COSVIG published for two years articles on *Qualenergia*, a bimonthly magazine on sustainable energy promoted by *Legambiente*, one of the main Italian NGOs on environmental issues. The general aim was to raise awareness on the heat under our feet and its usages, identifying benefits and limits, including barriers and solutions for its development.

Geothermal tourism, with museums, site visits and geoparks is a good opportunity to bring the public closer to this science and raise its awareness. While operators organise periodic visits to

Figure 5: The Undersecretary of State for the Ministry of Economic Development in 2019, during the first workshop of GEOENVI in Italy, on 17th April 2019.

powerplants (e.g., the initiative to open power plants in Italy, GECO demonstration sites on-site showcase in Iceland and Turkey). Geoparks combine the concepts of geoscience research, information and education at all levels, bringing the public into exceptional geological heritages and in contact with communities living there. Three examples of parks, belonging to the UNESCO's Global Geoparks Network and falling into geothermal areas, are Reykjanes (Iceland), Açores (Portugal), and the Tuscan Mining Park (Italy). The latter has a museum that explains the geothermal phenomenon through audio guides, panels, experiments, and virtual reality. In addition, a fairy tale to introduce kids to geothermal and its natural environment, was published in 2017 [31].

4. How to effectively and efficiently communicate research results

Grounding on the information collected and analysed from previous experiences, this chapter suggests recommendations and proposals to the scientific community, to better communicate geothermal science contents to a non-expert audience.

To effectively communicate geoscience results, it is essential to identify key messages and provide concise information using as much non-technical language as possible and a clear terminology, especially when addressing a non-technical audience [32]. When planning a communication strategy, it is important to consider the context of the given project in terms of area and related communities. This allows for a better understanding of the stakeholder landscape [33]. Similar considerations should be made when communicating geothermal science results in general when addressing a wider audience.

The communication should be adapted to the target audience, choosing the best dissemination tools and channels for the target group, combining formal and informal communication means [34]. Preferred forms of communication for citizens are articles in local newspapers, direct mails, websites [15] and social media. The choice of tools should consider the age of the audience. In fact, it is convenient to mix education and entertainment to actively engage an audience of teenagers (12 - 17 years old) on scientific topics: posters, videos uploaded on the Internet and various video games have been created over time for this purpose [34,35]. These communication tools are appropriate for reaching the public, but for policymakers, it is advisable to involve them through public initiatives, roundtables, and bilateral meetings, and send policy briefs or more simplified factsheets with specific recommendations for policies. These documents should also clearly articulate how the geothermal science results can contribute to meeting the objectives of EU policies.

Experts should also collaborate with traditional and non-traditional media and associations engaged in lobbying activities to raise public awareness on specific topics and increase the likelihood of research results influencing public policy. However, it should be noted that policymakers can be selective in their consideration of scientific or technical information within a policy context. They often prioritise scientific outcomes that align with short-term electoral mandates or have immediate socioeconomic implications [16], which may lead to the phenomenon known as NIMTO (Not-In-My-Terms-Of-Office) [36]. Therefore, strategic framing of research results to align with policymakers' priorities is crucial.

Regular audience updating, with weekly or monthly communications, gives people the opportunity to have valid opinions on geothermal and enables policymakers to predict the acceptability towards geothermal technologies and specific projects. Access to information (e.g., environmental data) and non-technical reports help to establish public trust [14] and provides opportunities to disseminate positive experiences. However, the public should not be overloaded with information and a systematic collection of open (e.g., online) and FAIR (Findable, Accessible, Interoperable and Reusable) data helps facilitate access. Sharing of reliable information is very important to gain public acceptance, as learnt from experience in Iceland. [37].

It is good to emphasise to the public what the possible socio-economic benefits of geothermal are, in terms of royalties for the territories, job creation, lowering of utility bills or attraction of tourism [33], but also for positive messages related to geoscience results, as done within the GEOENVI Project. However, disclosing possible risks linked to geothermal conveys a transparent and neutral communication and increases trust. This also allows comparisons and limits misinformation that can be generated by fake news and misconceptions.

As is in many geoscience-society contested sectors, simply explaining the technical science rarely motivates meaningful behavioural change among stakeholders. A more effective communication results from participatory engagement and dialogue, where individuals and communities contribute to the decision-making process [34]. Participatory processes and discussion groups also help to understand the preconditions and expectations of interlocutors [14, 26], forming the right environment for acceptance, as well as to raise awareness.

5. Conclusions

Communicating geothermal sciences, much like other geosciences, poses challenges when reaching a non-expert audience due to its inherent complexity. Yet, various publications and experiences underscore the crucial role of clear and effective communication in disseminating awareness, leading to increased acceptance and supportive policies for further development. Drawing from our experience in engaging non-experts, this research offers recommendations for communicating geothermal and related geosciences.

Clarity is key in effective communication: messages need clear identification, and concepts must be presented in an easy, concise manner. Tailoring communication strategies to specific projects, areas, and involved communities is vital. Each project's unique context requires consideration. Employing diverse communication methods—both formal and informal, traditional and non-traditional—is necessary to engage various geothermal stakeholders, including civil society, policymakers, and politicians.

Active two-way communication significantly enhances the social acceptability of geothermal projects. Despite considerable efforts to reach non-experts, significant opportunities persist in tackling the complex challenges of developing accessible and effective geothermal communication strategies, especially within international collaborative projects.

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Geological studies for regional and urban planning in Greece

Nikolaos Depountis [1,*]

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This article presents the importance of geological studies for identifying the most suitable areas for regional and urban planning in Greece. Termed as geological suitability studies, these studies aim to determine the geological suitability of land to protect the built environment from natural hazards and hazards associated with human interventions and activities. Key areas of focus include the exploitation of geological resources and the protection of the geological environment. In addition, the application of Geographic Information Systems (GIS) and Multi-Criteria Evaluation (MCE) for assessing geological parameters, which are crucial for the delimitation of geologically suitable zones, are discussed. Furthermore, the article explores how GIS and MCE can be applied in the development of geological suitability models.

Cet article présente l'importance des études géologiques pour identifier les zones les plus adaptées à l'aménagement régional et urbain en Grèce. Appelées études d'aptitude géologique, ces études visent à déterminer l'aptitude géologique des terres à protéger l'environnement bâti des risques naturels et des risques associés aux interventions et activités humaines. Les principaux domaines d'intervention comprennent l'exploitation des ressources géologiques et la protection de l'environnement géologique. En outre, l'application des systèmes d'information géographique (SIG) et de l'évaluation multicritère (MCE) pour évaluer les paramètres géologiques, qui sont cruciaux pour la délimitation des zones géologiquement appropriées, est discutée. En outre, l'article explore la manière dont les SIG et les MCE peuvent être appliqués au développement de modèles géologiques d'acceptabilité.

Este artículo presenta la importancia de los estudios geológicos para identificar las áreas más adecuadas para la planificación regional y urbana en Grecia. Denominados estudios de idoneidad geológica, estos buscan determinar la aptitud geológica del terreno para proteger el entorno construido de los riesgos naturales y los peligros asociados con intervenciones y actividades humanas. Las áreas clave de enfoque incluyen la explotación de recursos geológicos y la protección del entorno geológico. Además, se aborda la aplicación de Sistemas de Información Geográfica (SIG) y Evaluación Multi-Criterio (EMC) para evaluar parámetros geológicos, cruciales para la delimitación de zonas geológicamente aptas. Además, el artículo explora cómo SIG y EMC pueden aplicarse en el desarrollo de modelos de idoneidad geológica.

1. Introduction

In general, spatial planning includes all levels of land use planning ranging from urban, regional, and national spatial plans, to plans in the European Union and at international levels. In Greece, the geological studies elaborated for regional and urban planning are called geological suitability studies. These are mandated for the design of regional and urban plans at scales of 1:25,000 and 1:2,000 (or larger), respectively. Their primary focus lies on the protection of the built environment against geologically active phenomena that could trigger natural disasters, such as earthquakes, landslides, liquefaction, floods, ground subsidence, etc. These studies also address the exploitation of geological resources and the protection of the geological environment.

[1] University of Patras, Department of Geology, Greece
* ndepountis@upatras.gr

The preparation of geological suitability studies in Greece became more effective after the implementation of the Law N.2508/1997 [1] on sustainable residential development, which has been reformed several times in recent years. Its latest updated version is presented in Law N.4759/2020 [2] entitled "Modernisation of the regional and urban planning legislation". Furthermore, several Ministerial Decisions (MD) based on these laws have been published in Government Gazettes (GG), providing specifications and guidelines for the preparation of geological suitability studies [3,4] and other related studies [5,6,7,8].

The rapid development of Geographic Information Systems (GIS) has made the use of technological tools used in geological studies and site suitability more effective. Moreover, one scientific approach that can be further developed in the geological suitability studies is the Multi-Criteria Evaluation (MCE) methodology. The application of the MCE methodology proves efficient in the grading and delimitation of several geologically suitable zones. Various layers can be generated and graded in a GIS environment in order to produce a general geological suitability map for regional and urban planning.

2. General schedule of geological investigations for regional and urban planning in Greece

The process of examining geological conditions used in the context of regional and urban planning studies in Greece follows the following stages:

Stage A: During the initial planning of land use and development programs, a preliminary geological assessment is carried out, which mainly addresses geomorphological, tectonic, hydrological, hydrogeological, seismological, engineering geological and geological threat issues related to the areas under investigation. It describes and specifies the prevailing geological resources and submits proposals for the protection and enhancement of the geological environment. The geological survey at this stage excludes areas that generally are geologically unsuitable and divide the remaining areas into several zones of suitability. These zones are related to the prevailing geological conditions combined with the different land uses, such as residential, industrial and tourism. This assessment results in the formulation of proposals which are included in the approval decisions of the country's regional land-use plans or General Urban Plans (GUP).

Stage B: Subsequently, in the areas that have not be excluded from the previous stage, a more detailed engineering geological survey is carried out. Here, the physical and mechanical characteristics of the geological formations as well as the geological hazards threatening the potential residential areas and the natural environment are identified, mapped, and described in detail. This stage also includes an assessment of the problems that may arise during the foundation of the buildings. At this stage, the conclusions and recommendations of stage A are thoroughly reviewed, and, among other things, a final map is presented showing the geological suitability zones in the study area, described by one of the following proposals:

i. Suitable for residential development. In these areas, buildings of ordinary importance may be constructed. The building conditions may only mention observations that should be considered for optimal planning.
ii. Suitable for residential development under certain conditions. Specific conditions and restrictions are imposed on building in these areas.
iii. Unsuitable for residential development. There are serious reasons for excluding these areas from building.
iv. Doubtful for residential development. Further investigation is required either because there is insufficient data or because the existing legal framework requires it.

This work leads to the formulation of proposals which are included in the approval decisions of the country's local urban plans related to the geological suitability for residential development on the area under consideration.

Stage C: For areas where the stage B survey raises doubts as to their suitability due to lack of data, or indicates problems for which further investigation is required, additional specialised geological investigations shall be carried out. These investigations typically include geophysical surveys, micro-zone studies in areas of active faults, as well as geotechnical surveys and studies.

At each planning stage, the analyses and recommendations of geological investigations are communicated to the public planners, inhabitants, and private stakeholders so that they can participate in the decision-making process. Based on the conclusions of the geological investigations, the relevant administrative body issues a specific decision on the suitability for residential or other building development to accompany the planned regional and urban plan that is finally published in a Government Gazette (GG).

3. Geological Suitability Studies

3.1. Geological Suitability Studies for regional planning

These studies are compulsory for all Greek Municipalities, numbering 332, and they essentially represent the first step (Stage A) for the later urban planning (Stage B). These geological studies are governed by specifications which stipulate that the scale of the produced maps is 1:25,000 and that an initial overview of the existing geological condition is provided.

The area under investigation usually includes a few tens to several hundred squared kilometres and it includes all land-uses (residential or other urban uses, inland waters, infrastructures, forest, agricultural or environmentally sensitive areas).

The geological investigation carried out as part of these studies usually identifies three different areas related with the regional development:

i. Areas from a geological point of view for residential or other development (e.g., landfilling, cemeteries, wastewater treatment plans, and other infrastructures) related to building, to safeguard the built environment from natural hazards or risks from human intervention and activities;
ii. Areas for the protection of potential exploitable geological resources;
iii. Areas requiring conservation and enhancement of the geological environment.

Therefore, the information provided by the geological survey at this early stage of planning can be used in multiple ways: (i) as an initial approach of the general development of the municipality, (ii) in the planning of residential areas, showing the expected problems and restrictions that need to be imposed on building, (iii) in the exploitation of natural geological resources and (iv) in the assessment of certain initial geological parameters in infrastructure.

At this stage, as it has been mentioned in the introduction section, the MCE methodology may be used to produce geologically suitable zones of different grading and/or define zones of protection. For this purpose, three different categories of land-uses are examined (i) residential development and other uses related to building, (ii) geological resources, and (iii) the geological environment. Each of these categories is examined using different geological parameters and variables that are scored so that a graded scale of suitability or protection for each sub-area (or zone) is obtained. An example of this methodology is presented in Table 1.

The spatial determination of the relative geological suitability in each sub-area is carried out by the method of superposition of the corresponding thematic levels and their summation to define zones of different graded geological suitability by using the MCE methodology (Table 1) and the ArcGIS software [9]. Thus, the relative geological suitability is obtained as an algebraic sum of the grading determined for each class of each variable, according to the formula:

$$\sum_{j=1}^{n} B_{ij} \qquad (1)$$

where, n is the number of variables and B is the grade of each class i of each variable j.

According to Table 1, the geological suitability for residential or other

Table 1: Application of MCE methodology related to different land-uses.

Categories of land-uses for residential Suitabilty	**Parameters**	**Variables**	**Grading class**			
			3	**2**	**1**	**0**
(i) residential or other related uses	*Geomorphology*	*Slope inclination (%)*	*0-10*	*10-20*	*20-35*	*>35*
		Distance from coastlines	*>100 m*	*50-100 m*	*10-50 m*	*<10 m*
		Presence of unstable Geomorphological or Anthropogenic structures	*No*		*Yes*	
	Geology-Tectonics	*Presence of highly weathered or fractured Geological formations*	*No*		*Yes*	
		Distance from active/ Probably active faults	*>100 m*	*75-100 m*	*50-75 m*	*<50 m*
	Hydrology-Hydrogeology	*Distance from river Embankments*	*>100 m*	*50-100 m*	*10-50 m*	*<10 m*
		High water table (0-3m depth)	*No*		*Yes*	
	Geological Hazards	*Presence of landslide Phenomena*	*No*		*Yes*	
		Delimited century flood hazard areas	*No*		*Yes*	
	Seismicity	*Ground seismicity hazard category (according to the hellenic regulations)*	*A (very low)*	*B (low)*	*C (medium)*	*D, χ (high to very high)*
		Seismicity hazard zone (according to the hellenic regulations)	*Zone i (<0.12g)*	*Zone ii (0.12-0.24g)*	*Zone iii (0.24-0.36g)*	*Zone iv (>0.36g)*
	Engineering Geology	*Soils prone to liquefaction or settlements*	*No*		*Yes*	
		Ground subsidence	*No*		*Yes*	
(ii) geological Resources		*Existence of exploitable aquifers*	*Yes*		*No*	
		Existence of natural Surface water reservoirs	*Yes*		*No*	
		Existence of springs	*Yes*		*No*	
		Presence of industrial Minerals and ores	*Yes*		*No*	
		Existence of construction materials and aggregates	*Yes*		*No*	
		Existence of energy raw materials	*Yes*		*No*	
(iii) geological Environment		*Geo-environmentally Sensitive/protected areas*	*Yes*		*No*	
		Areas of degraded Geological environment	*Yes*		*No*	
		Geosites and monuments of nature	*Yes*		*No*	

related uses may be calculated by using six parameters, i.e., geomorphology, geology-tectonics, hydrology-hydrogeology, geological hazards, and engineering geology. Each one of these parameters is graded with the use of several graded geological variables and thematic maps and relative geological suitability zones are generated with the use of the raster calculator in the ArcGIS software.

All areas surveyed are graded according to their relative geological suitability in relation to the intended use, and the conclusions are considered in the land-use planning and the later urban planning.

3.2. Geological Suitability Studies for urban planning

These studies are compulsory in every case of urban planning or demarcation of a settlement. They are usually drawn up at a scale of 1:1,000 or 1:2,000 and aim to safeguard the built environment from natural hazards or hazards resulting from human intervention and activities.

The subject of these studies is:

i. The identification and separation of the areas to be built on as geologically suitable, unsuitable, and suitable under specific conditions;
ii. The description of the ground conditions and/or necessary ground improvement or other protective measures required for permitting construction in the designated suitable areas under specific conditions;
iii. The submission of proposals for the types of further studies and investigations required to clarify the geological suitability of the areas to be developed, to the extent that the data of the geological suitability study are insufficient or where more specific investigations are required.

In detail, the contents of such a study may investigate the following sections.

Geomorphology: A general and specific description of the geomorphology of the study area is given along with its relationship with geomorphological structures of the wider area. An assessment is also made of whether the geomorphology of the area is subject to changes due to geodynamic processes and human intervention. This includes factors like slope stability, soil creep, landslides, erosion and karstification phenomena. Human activities such as soil and rock exploitation, quarrying, landfilling, and soil embanking are also considered in this evaluation.

Geology: The geological data of the broader and study areas are systematically studied and mapped. The lithological composition down to a depth of 20 meters is also evaluated, based on field observations and other existing data. The most crucial tectonic features of the area are identified, and an assessment is made regarding their potential impact on buildings. In a broader context, the physical condition of surface rock and soil formations, along with their anticipated behaviour relevant to the study, is also thoroughly assessed.

Hydrology-Hydrogeology: All data and information relating to the hydrology and hydrogeology of the study area are examined, always in relation to the subject of the study.

Seismicity and Ground Hazard: The seismicity data for the wider area are provided and, an evaluation of the ground hazard within the study area is also conducted.

Engineering Geological Behaviour: The engineering geological behaviour of the predominant geological formations is assessed, and the geological conditions are identified and delimited on the geological map of the study area, particularly in places where geological disasters exist or there is a potential risk of occurrence. In general, all factors that may impact future foundations and structures are examined and mapped in detail.

Geological Suitability - Proposals: A fully justified classification of the area of interest is provided, categorising it into four suitability categories:

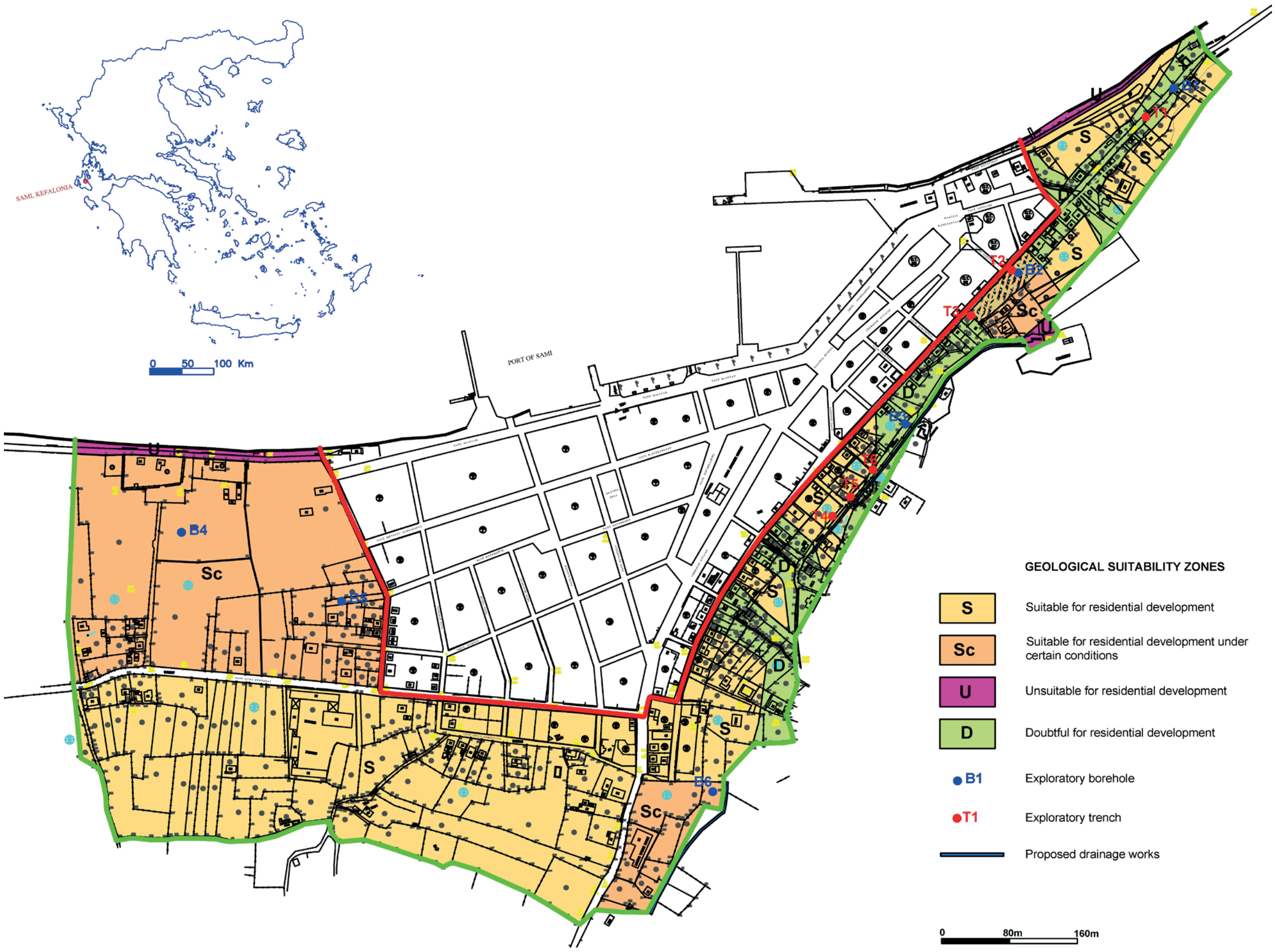

Figure 1: Geological Suitability Map of the town of Sami on the island of Kefalonia in Greece.

i. Suitable for building;
ii. Suitable for building subject to conditions (e.g., construction of protective works or other protective measures are mandatory);
iii. Unsuitable for building;
iv. Doubtful suitability for building where basic data is missing and further studies are required.

An example of a suitability map is given in Figure 1, where the geological suitability of the town of Sami, in the Kefalonia island is presented.

4. Cooperation of Geoscientists and Legislators

The cooperation between geoscientists and legislators in spatial planning is crucial for informed decision-making, sustainable development, and the well-being of communities. The following outlines how geoscientists and legislators can work together in the context of land-use planning:

i. Data Sharing and Collaboration: Geoscientists can provide legislators with valuable data on geological features, natural resources, land use patterns, and environmental conditions. Collaboration between geoscientists and legislative bodies ensures that policymakers have access to accurate and up-to-date information for effective spatial planning;
ii. Evidence-Based Decision Making: Geological research and data analysis can inform legislators about the geological suitability of different areas for specific types of development. Legislators can use this evidence to make informed decisions regarding land use zoning, infrastructure development, and environmental protection measures;
iii. Policy Formulation: Geoscientists can assist legislators in formulating policies that take geological factors into account. For example, regulations related to building codes, land use planning, and environmental protection can be crafted based on geological assessments and recommendations;
iv. Natural Hazard Mitigation: Geoscientists can identify areas prone to natural hazards such as landslides, earthquakes, and floods. Legislators can use this information to implement policies that restrict development in high-risk zones and enforce construction standards that enhance resilience against these hazards;
v. Infrastructure Planning: Geoscience expertise is crucial in planning infrastructure projects. Geologists can help legislators identify suitable sites for infrastructure development, ensuring that projects are built on stable ground and are less vulnerable to geological risks;
vi. Environmental Conservation: Geoscientists can assess the environmental impact of various spatial planning decisions. Legislators can use this information to create policies that promote sustainable development, protect natural habitats, and conserve biodiversity;
vii. Public Awareness and Education: Geoscientists and legislators can collaborate on public awareness campaigns to educate communities about geological risks and the importance of considering geological factors in spatial planning. Informed citizens can advocate for policies that prioritise geoscience-based decision-making;
viii. Legal Framework Development: Legislators can work with geoscientists to develop legal frameworks that support geoscience research, data collection, and dissemination. This can include funding for geological surveys, establishing standards for geological data, and promoting interdisciplinary collaboration between geoscientists and policymakers;
ix. Adaptive Planning: Geological data can inform adaptive planning strategies. Legislators can create policies that allow for flexibility in spatial planning, enabling adjustments in response to change geological conditions, climate change impacts, and emerging geological research findings;
x. International Collaboration: Geoscience and legislation are not confined by national borders. International collaboration between geoscientists and legislators can facilitate the sharing of best practices, data, and expertise, especially in regions prone to transboundary geological risks.

5. Discussion and Conclusions

Geological suitability studies for regional and urban development are essential for ensuring that regional and urban planning and infrastructure development consider geological parameters to minimise risks and maximise sustainability.

Current practices in geological suitability studies emphasise comprehensive assessments of several geological parameters, hazard mitigation, sustainability, and community engagement. These practices may include (i) Site Characterisation and Geological Mapping, (ii) Geotechnical Investigations, (iii) Geological Hazard Assessment, (iv) Hydrological and Hydrogeological assessment, (v) Sustainable Resource Management, and several others that depend on each country's regulations and needs.

In Greece, the corresponding geological suitability studies mainly focus on the protection of the built environment against geologically active phenomena (geological hazards), the exploitation of geological resources and the protection of the geological environment by using many of the above-mentioned practices during the different stages of planning. The main objective is to provide a geological suitability map with several zones and guidelines, on which zoning regulations are established. This ensures that high-risk areas are not developed for residential or critical infrastructure purposes. This is then followed by a specific geological suitability decision that accompanies the regional and/or urban plan published in a Government Gazette (GG).

Geographic Information Systems (GIS) play a crucial role in integrating geological data with other spatial data, allowing for comprehensive analyses and visualisation of geological suitability parameters and variables. With the use of the discussed MCE methodology a more comprehensive mapping is generated that is very useful in the establishment of more detailed spatial and urban plans.

The geological suitability studies that are carried out to define areas suitable for building in Greece contribute to the urban and spatial planning and the development of the country. These studies are crucial for creating resilient and safe urban environments that can withstand geological challenges and contribute to the overall well-being of their residents.

However, climate change considerations, such as assessing the impact of rising sea levels on coastal urban areas, the impact of forest fires, or the impact of flooding in lowland areas are in their early stages and have not yet been mandatory in land-use planning. This because both the political parties and the local population in Greece have not yet been convinced that climate change will shortly and severely affect large arable and habitable areas. Recently, the region of Thessaly, Greece, experienced a natural disaster named Storm Daniel. The resulting floods in the lowland areas of Thessaly impacted more than 720 km2 of arable and habitable areas. Consequently, new land-use plans must now be formulated to guide development in the affected areas over the next decades.

Given the evolving nature of geological conditions and climate change impacts, it is important to adopt adaptive planning strategies that allow for adjustments and updates to existing and new land use plans as new climatic data and information become available. Communicating this new information with local communities and stakeholders is essential. It ensures the incorporation of their concerns and perspectives into the planning process, aligning geological suitability studies with community needs, expectations, and climatic changes.

Furthermore, by fostering cooperation between geoscientists and legislators, land-use planning can be more resilient, sustainable, and responsive to the geological complexities of the environment. This collaboration ensures that policies and regulations are grounded in scientific understanding, leading to more effective spatial planning outcomes. In the author's opinion, the flood hazard management plans that have been published in the Government Gazette (FEK) for the 13 regions of Greece should become mandatory in spatial planning, especially after the natural disaster that occurred in the region of Thessaly. The rapid adaptation of these plans to land-use planning, and the corresponding geological suitability studies can be achieved by the cooperation of geoscientists and legislators to produce more effective and publicly acceptable land-use plans.

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Policymaking and geosciences: the case of Critical Raw Materials in Italy

Mauro Lucarini [1,], Fiorenzo Fumanti [1], Lucio Martarelli [1] and Monica Serra [1]*

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The geoscience knowledge has improved our ability to access clean water, cultivate food, mitigate natural hazards and enhance the economy. It also plays a significant role in policymaking, often supported by an interdisciplinary approach. The sustainable energy transition requires a larger supply of raw materials within the framework of a circular economy. In Italy, despite a rich history of mining, a decision was made to import the majority of mineral resources from abroad, as it was more economically sustainable. However, over the past decade, there has been increased awareness, particularly after the introduction of the EU Green Deal. The Italian Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA) is actively supporting the mining sector, by coordinating technical panels and discussions on eco-friendly raw material perspectives at the national level. Additionally, ISPRA is developing a Geodatabase as a tool to promote the sustainable production of both primary and secondary mineral resources, while also contributing national and regional policies.

Les connaissances géoscientifiques ont amélioré notre capacité à accéder à de l'eau potable, à cultiver de la nourriture, à atténuer les risques naturels et à renforcer l'économie. Elles jouent également un rôle important dans l'élaboration des politiques, souvent soutenue par une approche interdisciplinaire. La transition énergétique durable nécessite un approvisionnement plus important en matières premières dans le cadre d'une économie circulaire. En Italie, malgré une riche histoire minière, la décision a été prise d'importer la majorité des ressources minérales de l'étranger, car cela était plus durable économiquement. Cependant, au cours de la dernière décennie, une prise de conscience s'est accrue, en particulier après l'introduction du Green Deal de l'UE. L'Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA) soutient activement le secteur minier en coordonnant des panels techniques et des discussions sur les perspectives de matières premières respectueuses de l'environnement au niveau national. De plus, l'ISPRA développe une géodatabase comme outil pour promouvoir la production durable des ressources minérales primaires et secondaires, tout en contribuant également aux politiques nationales et régionales.

El conocimiento en ciencias geológicas ha mejorado nuestra capacidad para acceder a agua limpia, cultivar alimentos, mitigar riesgos naturales y potenciar la economía. También desempeña un papel significativo en la formulación de políticas, a menudo respaldado por un enfoque interdisciplinario. La transición hacia una energía sostenible requiere un suministro más amplio de materias primas dentro del marco de una economía circular. En Italia, a pesar de una rica historia minera, se tomó la decisión de importar la mayoría de los recursos minerales del extranjero, ya que resultaba más económicamente sostenible. Sin embargo, en la última década, ha habido un mayor conocimiento, especialmente después de la introducción del Pacto Verde de la UE. El Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA) de Italia está apoyando activamente al sector minero, coordinando paneles técnicos y discusiones sobre perspectivas de materias primas ecológicas a nivel nacional. Además, ISPRA está desarrollando una Geodatabase como herramienta para promover la producción sostenible tanto de recursos minerales primarios como secundarios, al mismo tiempo que contribuye a las políticas nacionales y regionales.

1. Introduction

The water, energy, and raw materials supply should be based on assessments and methodologies for reducing environmental impacts and risks. This is essential to support a deeper understanding and more effective management of the "subsurface layer". To support policymakers, industry stakeholders, and decision-makers, a geological knowledge base, complete with objective and seamlessly accessible data, information, and expertise, is a necessity.

[1] ISPRA, Istituto Superiore per la Protezione e la Ricerca Ambientale
* mauro.lucarini@isprambiente.it

The role of geological knowledge lies in the transformation of acquired data into valuable data, which is then shared with the aim to support policymakers and various sectors of society, including academia and research, industry, stakeholders, investors, non-governmental organisations-NGOs, and the public. Presently, there is an increasing demand for information within society, as European citizens increasingly seek immediate access to the information essential for gaining a better understanding of the environment, hazards, and the imperative of sustainable natural resource management.

The development of an integrated and multidisciplinary approach to applied Earth Sciences is necessary to support European policies, that pertain to the understanding, utilisation, and management of the Earth's subsurface resources. Furthermore, this approach is vital in addressing threats generated by anthropogenic activities. It plays a significant role in fostering national and regional policies that address natural resources and geological hazards.

Geosciences play a pivotal role in enabling the increasingly urgent energy transition and can serve as a catalyst for innovation and business, ultimately facilitating a sustainable and socially viable shift towards clean energy. This energy transition will further increase the reliance on new technologies and low-carbon energy systems, all of which are intrinsically linked to geoscientific knowledge, supplies and solutions [1].

Academia, industry, and government should identify high-priority and short-duration objectives concerning the energy-transition strategy and government policies. As a mid-term priority, it is crucial to enhance social awareness regarding the significant role of geosciences in advancing the goal of achieving net zero emissions across the EU.

Geoscientists recognise their responsibility in contributing to an effective and fair energy transition. This includes providing relevant education and training, collaborating for efficient and professional deployment of expertise, offering evidence-based information for both public understanding and policy formulation, developing community trust by actively listening, understanding and being receptive and responsive to concerns [1].

Finally, policy tools such as strategic planning, the enforcement of social and environmental best practices, and the recognition of the importance of mineral resources in land use planning should be implemented by EU Member States. This is especially critical in areas with limited geological knowledge regarding mineral deposits.

2. Global mining context and policy-making in Italy

The development of renewable energy sources and other high technology applications will require new infrastructure that will consume a varied assortment of minerals compared to current applications. This does not only include the 'critical' metals like rare earths, but also vast quantities of common commodities such as copper, steel, and cement.

International programmes have assembled data on resource demand and governance of natural resources, such as the International Resource Panel of the United Nations Environment Programme. They have conducted significant research on mineral availability and governance but, so far, their primary emphasis has been on knowledge exchange, with limited regard to the development of policies addressing resource scarcity [2].

A strategic medium to long term vision regarding Critical Raw Materials (CRM) is also essential for industrial policy. The availability of CRMs, given the global demand, can pose challenges due to their variable geomineralogical concentrations, dependence on technological factors, and the economic policies of producing nations. Furthermore, unpredictable factors, ranging from conflicts to pandemics, can disrupt production and impact the supply chain, as currently observed by the challenges in sourcing raw materials and semi-finished products for national and European industries.

To address these issues, major mining companies must confront the related challenges by adopting new approaches and ideas that are inherently centred on sustainability. The era of critical minerals has dawned and it is regarded as the most momentous transformation the industry has witnessed in recent decades, with national governments assuming an ever-increasing role. Given the current surge in demand and elevated risk in supply chains, larger companies have formed alliances, instituted new policies and mobilised funding to secure access to critical minerals [3].

Decarbonisation also plays a crucial role, in fact mining companies must increase production to meet the rising demand for critical minerals and other products essential for the energy transition, all while reducing their carbon emissions. The drive to decarbonise the economy, as mandated by climate policies, hinges on the transformation of our energy system from fossil fuels to an electrification-based architecture. In addition, this shift necessitates a reconstruction of the mining supply chain. It is essential to recognise that depending on third countries, as illustrated by the challenges in reducing reliance on Russian gas, poses significant risks.

The energy transition will result in an increased demand for critical metals including copper, lithium, nickel, manganese, cobalt, graphite, molybdenum, zinc, rare earths, and silicon. It is important to note that, China predominantly controls the aforementioned metals and holds a significant portion of their refining sectors. Without sufficient extraction and refining capacity, Europe will remain highly dependent on countries that might impose restrictions at their discretion. The presence of a monopoly has already led to restrictions on the export of rare earths, crucial for various strategic technological products, including wind turbines, electric vehicles, smartphones, and weapons, as well as components for solar panels. Furthermore, it is essential to understand that the countries where the mineral supply for key battery materials, such as Australia (50%), Chile (20%), and Argentina (10%) presently dominate the production of lithium mines. It is uncertain whether the increase in production will proceed as planned.

Geopolitical uncertainty has complicated the picture, sowing doubts about the provenance of critical minerals. In response, governments around the world have taken swift action to form alliances, developing policies and legislation, and financing initiatives that will stabilise the supply of critical minerals. These actions include, forging strategic partnerships between governments or trade agreements focused on collaborative efforts in critical minerals (alliances

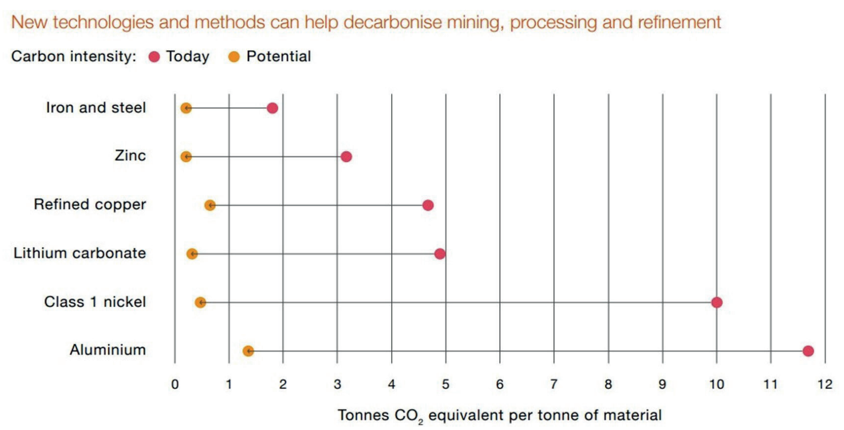

Figure 1: Analysis conducted by PWC based on IEA data, highlighting the potential for decarbonisation through reduced consumption of iron, zinc, lithium carbonate, and aluminium, particularly in energy production. Source: IEA, International Energy Agency.

Figure 2: Salt mine in Realmonte, Agrigento, Sicily. Source: Fabrizio Giraldi.

and agreements), enacting laws, policies or regulations to safeguard and guide the development of critical minerals and supply chains (policy and legislation), and offering direct government funding or government-backed funds to support critical minerals and supply chain initiatives (forms of funding).

As mentioned earlier, the mining sector plays a crucial role in the energy transition by providing raw materials for renewable energy and climate technologies. Meeting the global emissions reduction targets, as outlined by the International Energy Agency (IEA), will require an increased production of mining products. This includes a greater demand on steel for wind turbines, additional copper for transmission lines and electrical components, a higher volume of lithium for batteries, as well as a growing need for rare earths in electronics (Figure 1).

The production and supply of mineral raw materials from mines and quarries are of strategic importance for the economy, both within the European Union and at a national level. While the EU is a significant player in the production of construction and industrial minerals, the European industry relies heavily on imports for many raw materials, even from countries where mining and sourcing practises may not always be sustainable. Hence, Europe must improve the management of its untapped mineral resources, including the adoption of more efficient recovery and recycling strategies. In this context, we are progressing towards the challenging task of combining economic competitiveness in production with environmentally and socially acceptable impacts through the concept of "sustainable mining" [4, 5].

EU member states are actively assessing their future requirements for critical minerals, motivated partly by the implementation of the CRM Act. In fact, as part of the recent CRM Act [6], the EU has announced its intent to establish a central agency for critical minerals. The Act outlines preliminary plans to "aggregate demand" and establish a procurement system for end-users of CRM within the EU. The objective is to domestically source at least 10% of the annual demand by 2030. Given consumption forecasts and considering the current state of global supply, most of the metals used in the energy transition process will face a structural shortage in the next years.

In this context, the Italian strategy must place significant attention on establishing joint ventures with foreign mining groups, to facilitate national and international mining ventures. This approach is essential because, apart from addressing the extraction and refining shortfall, Italy will also need to bridge the gap in terms of access to the required financial resources and expertise. Such an effort should not only encourage the development of existing Italian industrial entities, but also foster the emergence of new ones through public-private collaborations.

In Italy, despite a decrease in production recorded since 2008, the extractive industry for non-energy mineral resources remains an important economic sector (Figure 2), particularly for industrial and construction minerals. Thus, Italy should take on the task of launching a shared strategy between the government and regional authorities, in line with their respective competencies. This aims to maintain and strengthen the competitiveness of country's mining industry, with a focus on sustainable management and development. This involves establishing resource-efficient value chains and increasing the capacity for reuse and recycling (Figure 3) [7, 8].

Abandoned mining waste has the potential to serve as a significant source of secondary raw materials. However, Italy must accelerate the process of revising its existing legislation. The primary focus should be on updating the regulations pertaining to abandoned mining

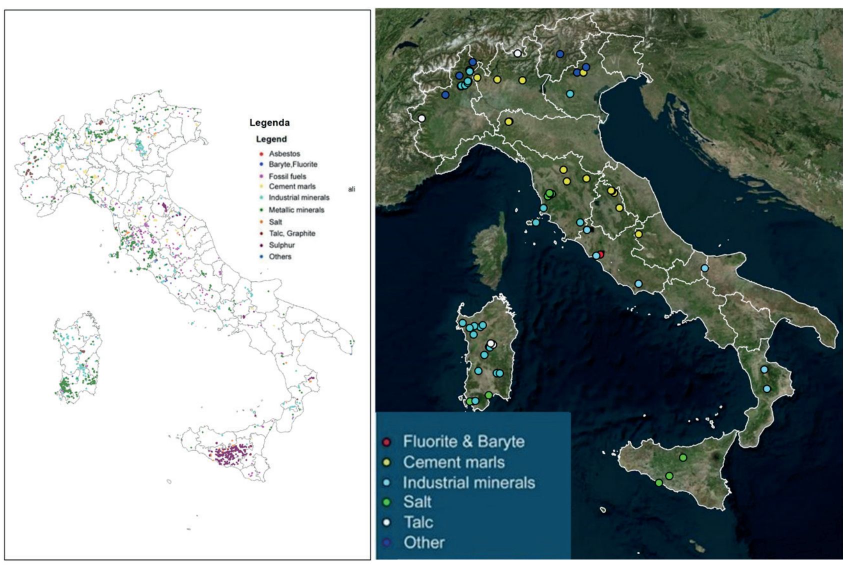

Figure 3: Distribution of Italian mines operating between 1870 and 2018 (left) and current mining concessions (right). Source: ISPRA [8].

waste. This is crucial because the Italian Legislative Decree 117/2008, which addresses mine waste management in alignment with the European Directive 2006/21/CE, does not specifically cater to waste for the purpose of mineral supply.

3. The "old-fashioned" legislative framework in Italy and the main proposals for regulatory changes

The mining legislation in Italy still dates back to the Royal Decree of July 29, 1927, No. 1443, which classifies (art. 2) the extractive industries into two categories: those involving strategic minerals (first category), such as mines and those related to minerals with a lesser economic impact (second category), such as quarries and peat bogs [9].

Therefore, the main distinction lies between the deposits subject to mining (excluding peat), which fall under the public law and are state-owned, subject to a concession procedure, and the quarry reservoirs which are under the private law, subject to an authorisation process and belong to the land owner.

Since the 70's Italy has initiated a transfer of powers from the Central State to the Regional Governments regarding the governance of the extractive activities sector. This shift in responsibility occurred through the Presidential Decrees 2/1972 and 616/1977, which facilitated the transfer of functions and competencies to the Regions concerning the management of quarries.

Regarding mining activities, research concessions and exploration permits have been governed by Presidential Decree No. 382 of April 18, 1994. Later, Constitutional Law No. 3/2001 restructured the sector granting primary authority to the Regions and assigning orientation and coordination activities to the central government. Consequently, post-2001, Regions began enacting local mining laws that reflected the Royal Decree. Prospecting and exploration of mineral deposits requires a license according to the Title II (Mines) – Chapter I (Mining explorations) of Royal Decree 1443/1927, Presidential Decree 620/1955 (decentralised competencies for concessions on mineral oils and liquefied petroleum gases), and Presidential Decree 382/1994 (permits and concessions). Therefore, by holding only a permit, research and extraction operations can be performed. The exploration permits are subject to EIA (Environmental Impact Assessment) legislation, which is administered by the Ministry of Environment and Energy Security (MASE). If exploration yields positive results, the permit holder, can request a mining license for ore extraction.

Figure 4: The "Monteponi red mud heaps", composed of mineralogical and metallurgical processed waste (left), Sardinia - Italy. The "fine basin of Masua" comprised of tailing ponds (right), Sardinia - Italy. Source: EU Network IMPEL, Management of Mining Waste Project, 2020-2022.

The production concession is regulated by the articles 14 to 44 of the Royal Decree 1443/1927. This concession is always a temporary concession and is ordained by a deliberation of the competent authority including:

1. The concessionaire's data and address information;
2. Duration of the concession;
3. The type and extension of the mine and of its borders;
4. The concession fees (royalties).

The concession is conducted through deliberation at the local government level in each individual Region (Royal Decree 1443/1927; Legislative Decree 112/1998).

Eventually, for each extraction activity an EIA is required: a national level EIA for prospecting, researching and producing offshore oil; a regional level EIA for inshore quarries and peat bogs, producing more than 500.000 m^3/yr or covering an area greater than 20 hectares. For inshore mineral deposits, a Regional Screening Procedure is employed (art. 2 Royal Decree 1443/1927).

As previously mentioned, administrative and technical skills relating to the extraction of non-energy minerals have been delegated to the Regions at various points in time (quarries: Presidential Decree July 24th, 1977, No. 616; mines: Legislative Decree March 31, 1998, No. 112 and Legislative Decree June 22, 2012, No. 83). Additionally, all regions have legislated on the matter at different times. The absence of national guidelines has generated diversified regional planning approaches and heterogeneous databases in terms of data quality and completeness.

The existing situation requires the collection and harmonisation of available data to establish a coherent national framework. It is important to note that Italy currently lacks a national inventory of ceased, active or operative non-energy mining activities.

Given the mentioned Italian legislation, dating back to almost a century, a strong innovative push is required for legal reassessment of abandoned waste (Figure 4). This, in turn, would allow the reuse and recovery of materials in storage facilities, which are currently posing ecological, health, and structural challenges.

Given the current decentralisation of mining sector regulations in Italy, it is advisable that the competent ministries and public authorities, collaborate in a coordinated manner, taking into account the national, regional, and provincial dimensions. They should provide clear guidelines and strategic programmes for a future reactivation of mining activities.

ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale) is currently working with the competent ministries and with local stakeholders to develop regulatory solutions that allow the sustainable management of mining activities, with regard to the management and recovery of mining waste. This effort aligns with the requirements outlined in European Directive 2006/21/EC and Italian Legislative Decree No. 117/2008.

4. Mining strategy, informative database, and mining mapping in Italy

In addition to the possibility of improving the current regulatory framework, it is essential to be able to recover, all the information linked to solid mineral extraction activities. This is crucial for quantifying geo-mineral resources, ensuring environmental protection and

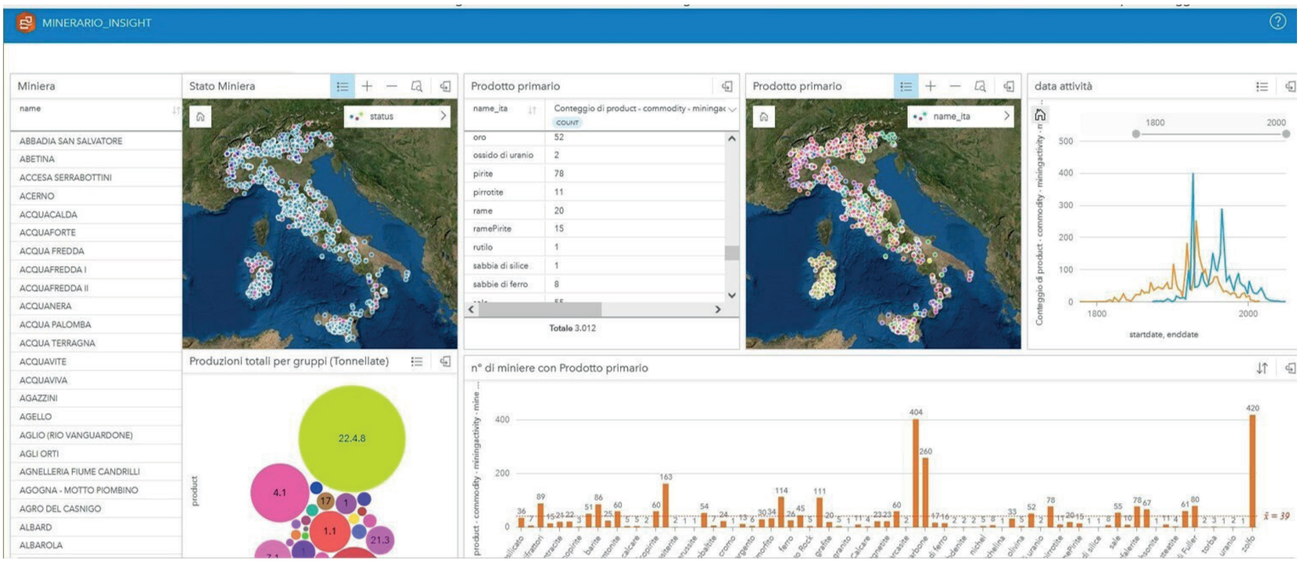

Figure 5: Prototype of the GeMMA Database. Source: ISPRA [10].

protecting cultural heritage. With this regard, the Geological Survey of Italy at ISPRA is actively developing the National Geological, Mining, Museum and Environmental Geodatabase (GeMMA Project) [10]. This effort includes specific projects collaborating with the competent regional bodies and will be closely linked to the planned creation and updating of the Mining Map of Italy (currently originating from 1973) [11].

This database (Figure 5) will contain all relevant information related to Italian geological mapping projects (e.g., CARG Project-Italian Geological and Geothematic Cartography project), historical geological maps, national census of active mines and quarries, data from regional and provincial databases and mining plans, inventory of historical mining sites, network of mine national parks and museums, etc. The main purpose of the GeMMA project is to define the national situation of mineral resources from mines and quarries including the geological, environmental, cultural, and economic aspects, with particular attention to the environmental impact of mining practices and the potential exploitation of the decommissioned mining assets and the extracted waste that has piled up over time.

The general objective of data harmonisation is to facilitate the evaluation of national resources with the following objectives in mind:

1. Supporting the development of a new integrated national mining strategy;
2. Re-establishing the foundation for nurturing skills that will allow Italy to sustainably manage its own resources;
3. Ensuring a substantial presence in international projects, contributing to a responsible supply of solid mineral resources.

The ultimate goal is the identification of areas considered suitable, for the issuance of operational research permits. These areas are determined through the intersection of mining potential and anticipated social and environmental impacts. This integration is part of a procurement plan that centres on the principles of a circular economy and environmental protection.

The first step involves a geological mapping of the country, under the leadership of the National Table for Critical Raw Materials shared between MIMIT and MASE. Simultaneously, it is necessary to update regulations regarding mining activities, which are still rooted in the Royal Decree No. 1443 of 1927. The government will have to recognise the importance of mining, in the protection of the national interest and actively intervene in the supply strategy. Consequently, at sites where raw material deposits are identified as underutilised by the national economy, it is imperative to leverage this availability as a bargaining tool to secure essential raw materials of immediate national interest from other countries [7].

Similarly to other European countries, the objective is to achieve a new national ore deposits vision, represented by a new and innovative Mining Map of Italy, which also includes abandoned waste, by the associated GeMMA Database (both, the new Mining Map and the Database are still prototypes, not published on the ISPRA website) and by a Catalogue of Conceptual Models, which describes groups of similar deposits in Italy. This initiative is situated within the context of environmental sustainability and forms a vital component of a broader procurement strategy for mineral raw materials. It is worth noting that the latest version of the Mining Map of Italy [1] was created within a completely different social-economic context compared to the present day.

To date, all the active quarries and mines across the national territory have been identified and georeferenced within the GeMMA prototype. Approximately 90% of the mines that have been operational since 1870 have been successfully located. Each coded mining site is linked to data sources such as mining site type, activity state, extracted ore type, management type and the environmental condition of the site. The estimation of resources and reserves poses greater challenges, primarily due to the division of responsibilities attributed to the regional authorities under Italian legislation. Therefore, for the successful execution of this project, ISPRA is coordinating a Thematic Table of the Italian Geological Services Network, involving the participation of the Regional Offices for Mining and collaborating with the Italian Institute for Statistics (ISTAT), MIMIT and MASE. Through these efforts, the Geological Survey of Italy aims to transform the GeMMA Database into a valuable tool for the development of national and regional policies oriented towards the sustainable extraction and efficient use of primary and secondary mineral resources within the framework of a circular economy [12].

5. Conclusions and future perspectives

The notion that Italy lacks sufficient mineral raw materials must be dispelled through a new national sustainable procurement strategy that integrates mining within the principles of the circular economy. Assigning ISPRA the coordinating role for creating the new National Mining Map and developing sustainability criteria for mining activities will facilitate the application of best available practices, minimising environmental impacts. This will be achieved through the establishment of a monitoring and control programme that covers the entire life cycle of mining activities. Numerous scenarios developed by international institutions concur that, in the future, solid minerals will replace conventional fuels.

Clearly, certain specific measures should be taken into consideration to ensure efficient mining [2], particularly by policymakers:

1. CRM extraction must be socially and environmentally acceptable;
2. The promotion of a system for tracking mineral usage throughout the entire value chain, from source to the end of life;
3. Encouraging private-public collaboration to develop new techniques for mineral exploration in new locations, fostering data sharing between industry and geological surveys;
4. Support for investments and research in new mineral extraction technologies;
5. Enhanced coordination between industry and governments to achieve good environmental practices, proactive and effective stakeholder engagement, and the coexistence of mining with other land uses;
6. The development of maps and inventories that illustrate the availability of recyclable metals, while establishing internationally recognised standards for recyclability.

To achieve these goals, it is important to stress some focal points, ranging from the educational sector to the streamlining of bureaucratic practices, and extending to the attainment of social acceptance in the mining sector.

In fact, in addition to the issues, the shortage of talent is becoming an almost existential challenge for mining companies, particularly those operating at remote sites. Therefore, it is considered essential to collaborate with governments and with local communities to effectively communicate the role of the extractive industry in the energy transition. Furthermore, investments in the education and training of specialists in the sector are vital, potentially retraining staff to align with the concept of sustainable mining. Economic and training investments should be closely integrated to guarantee that the system can effectively support a sustainable energy transition [3]. Furthermore, it is essential to highlight that the continuous decline of the mining sector could potentially lead to a loss of expertise in the sector, as well as a higher risk of disinvestment in research and education. This is because young, well-educated scientists may relocate to other regions. To mitigate these impacts, the European Union has invested heavily in research and innovation activities through the Framework Programme Horizon 2020, for the period 2014 to 2020, and plans to continue investments in Horizon Europe, for the period 2021–2027. As for Italy, it is actively participating in such projects in order to try to align itself with the EU mining strategy. Moreover, mining serves the essential purpose of supplying raw materials to meet the needs of the global population. Nevertheless, mining is often perceived negatively, possibly due to past instances that have left lasting marks on former mining regions, particularly in Italy. Consequently, companies in the sector encounter challenges when attempting to effectively and promptly communicate with the public to achieve a positive response (Figure 6). The 'Social License to Operate' (SLO) is the key for integrating sustainability into the mining sector [13]. It extends the operator's liability or operating license throughout the entire lifecycle of the mining business. The company acquires this license from the main stakeholders, through permits, environmental impact studies, geomonitoring and risk management systems. Additionally, it is supported by building a relationship of trust and transparency with local communities and governments, actively engaging them in the planning process right from the outset. Achieving prior consent for the initiation or reactivation of a mining operation requires substantial credibility on the part of the mining stakeholders, particularly in Italy.

All these factors may be taken into consideration in the future when it comes to investments in extractive industries and could influence the decision to grant a SLO at the European level [13].

In summary, a mining process can only be considered sustainable when the utilisation of deposits is also sustainable, necessitating equal consideration of eco-

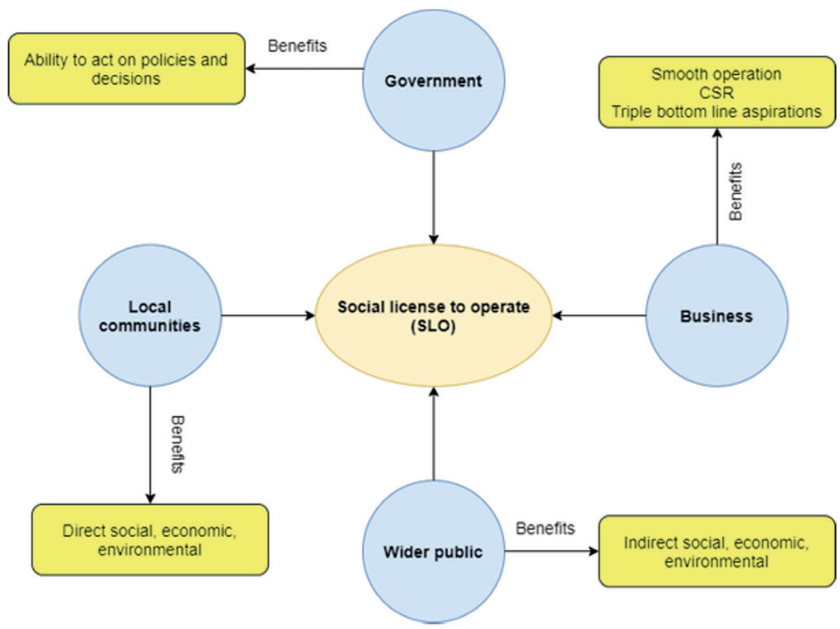

Figure 6: Flowchart illustrating the primary stakeholders involved in acquiring a social license to operate (SLO) and their key advantages. Source: [13].

nomic, ecological and social dimensions [14].

Eventually, mining companies bear the costs of operational research, often supported by state contributions. However, the subsequent assignment of permits should be simplified for mining companies with a proven track record and in areas previously identified as promising by relevant authorities. In this context, geological documentation is important for achieving accuracy in mining. The new National Mining Map of Italy will serve as a fundamental tool in the strategy, fostering the alignment of environmental, social, and economic conditions in the regions. One of the primary objectives is to delineate areas suitable for the issuance of operational research permits within our territory.

This underlines the fundamental principle that all EU members, particularly Italy, must invest in research and training to bridge the gap with the dominant mining economies in the supply of raw materials. Italian governance stands to gain a new perspective on policymaking by promoting research and innovation investments, starting from its robust geological knowledge base.

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Science-based data service to accelerate geothermal developments in Hungary

Annamária Nádor [1, *]

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Hungary's rich geothermal resources provide a real option to tackle the present energy crisis, decrease the country's high gas dependency and decarbonise its heating sector. Nevertheless, geothermal project development faces some barriers, one of the most important ones is the geological risk of the unknown reservoir properties. One powerful tool to mitigate this risk is to increase the knowledge of the subsurface and provide geoscientific data availability to project designers. The presented Hungarian case study shows a systematic development of such data service, comprising a public web-map based geothermal information system (OGRE) and tailor-data packages developed on the basis of an indicator system that considers the 3 most important factors: reservoir types (R), heat market conditions (H) and the rate of exploration (S).

Les riches ressources géothermiques de la Hongrie offrent une véritable option pour faire face à la crise énergétique actuelle, réduire la forte dépendance du pays au gaz et décarboner son secteur du chauffage. Néanmoins, le développement de projets géothermiques se heurte à certains obstacles, l'un des plus importants étant le risque géologique lié aux propriétés inconnues du réservoir. Un outil puissant pour atténuer ce risque consiste à accroître la connaissance du sous-sol et à fournir des données géoscientifiques aux concepteurs de projets. L'étude de cas hongroise présentée montre un développement systématique d'un tel service de données, comprenant un système d'information géothermique public basé sur une carte Web (OGRE) et des packages de données sur mesure développés sur la base d'un système d'indicateurs qui prend en compte les 3 facteurs les plus importants : les types de réservoirs. (R), les conditions du marché de la chaleur (H) et le taux d'exploration (S).

Las abundantes fuentes geotérmicas de Hungría ofrecen una opción real para abordar la actual crisis energética, reducir la alta dependencia del país del gas y descarbonizar su sector de calefacción. Sin embargo, el desarrollo de proyectos geotérmicos se enfrenta a barreras, siendo una de las más importantes el riesgo geológico asociado a propiedades desconocidas del yacimiento. Una herramienta poderosa para mitigar este riesgo es aumentar el conocimiento de la subsuperficie y proporcionar disponibilidad de datos geocientíficos a los diseñadores de proyectos. El estudio de caso húngaro presentado, muestra un desarrollo sistemático de este servicio de datos, que incluye un sistema de información geotérmica (OGRE) basado en un mapa web público y paquetes de datos personalizados desarrollados sobre la base de un sistema de indicadores que considera los tres factores más importantes: tipos de yacimiento (R), condiciones del mercado de calor (H) y tasa

1. Introduction

Hungary's excellent geothermal potential – due to its favourable geological setting, including high heat flux and an above average geothermal gradient, coupled with extensive and deep-lying aquifers – is well known. Despite the fact that Hungary is among the top 5 countries in Europe in direct use (1,02 GW_{th} installed capacity, 2508,26 GWh/yr annual production in 2021 [1]), there are still a lot of untapped opportunities especially in the heating sector. The current energy crisis urged to take this chance, as 82% of Hungary's annual gas consumption (9,4 BCM) is imported from Russia, and the share of gas in heating buildings is about 50%. Recent analyses [2] revealed, that even with current technologies the present 6,5 % share of geothermal (3090 TJ) in the heating sector could be increased to 25-30% within 5-10 years, thus geothermal could replace about 1 BCM gas, primarily in the residential heating sector.

Numerous barriers of deep geothermal project development have been identified, but it is commonly agreed that one of the most important hurdles is the high geological risk at the exploration phases due to uncertainties in the geological knowledge of the subsurface, coupled with significant capital expenditures resulting from the high drilling costs. This unfortunate matching of high risks and high costs often discourage investors and impedes project development. One way to deal with this problem is the establishment of geological risk mitigation schemes [3] which successfully operate in a few European countries, however, requires significant public and/or private funds to function. The other alternative is to increase the knowledge of the subsurface and make geoscientific data publicly available, thus minimising the risks that a borehole does not discover the suitable reservoir. Collecting, assessing, storing, and making geoscientific data openly available is generally the role of National Geological Surveys, therefore their role in supporting the development of successful geothermal projects is inevitable. This paper presents a showcase of a systematic approach of building and making geoscientific data accessible to

[1] Senior Geologist; Supervisory Authority for Regulatory Affairs
* annamaria.nador@sztfh.hu

assist geothermal project development in Hungary. This organised work followed the FAIR database principles as much as possible (**F**indable, **A**ccessible, **I**nteroperable, **Re**-usable).

2. Public data service to de-risk geothermal projects

2.1. Online geothermal information platform ("OGRE")

Hungary's first online Geothermal Information System (OGRE) aims to provide up-to-date and reliable geological, hydrogeological and geophysical data and information about the country's geothermal energy resources via a user-friendly website with public access. The GIS based web-map system is available in Hungarian and English. It was developed by the Hungarian Geological Survey from state funds and was launched in 2020. The system is a thematic arrangement and update of already existing geological, geophysical, and hydrogeological databases relevant to geothermal energy. It was established with the aim to help the preparatory work of national and international consortia aiming to invest into new geothermal projects in Hungary, as well as the every-day work of policy makers. Furthermore, it aims to assist higher level education and also provide useful information to the public interested in geothermal energy. Maps presented on the portal are based on regional geoscientific models, therefore they provide a large-scale overview about the geothermal conditions of a certain territory; however, they do not replace detailed exploration and pre-feasibility studies necessary for a concrete project at local scale.

The web-map system is comprised of a set of *maps* edited for the territory of the entire country (e.g. geological horizons bounding the most important geothermal aquifers, isotherm maps characterising the subsurface temperature conditions, maps showing the 3D spatial distribution of the most important geothermal reservoirs, etc.); *point features* (e.g. thermal water wells, boreholes, locations of geothermal projects, etc.) and *polygons* (e.g. thermal groundwater bodies, concessional areas, etc.). These are arranged into various thematic groups, which can be visualised up to request and can be combined with each other. The different thematic groups and their specific layers generally show metadata. An exception is the group of thermal water wells, where the system provides detailed data of 1720 wells (e.g. depth of screened intervals, aquifer lithology, groundwater level, yield, temperature, hydrogeochemical character, utilisation type, etc.).

With a detailed map series of geophysical coverage, as well as maps showing the location of deep boreholes (including hydrocarbon exploration wells), OGRE provides a unique opportunity to search for data of a certain territory for a detailed prospection. Data themselves are not provided through the portal, but are available at the Sate Geological, Geophysical and Mining Data Store.

2.2. Planning geothermal data packages

Whilst OGRE provides an exclusive opportunity to get an in-depth overview of Hungary's geothermal conditions and the most prosperous areas, it does not make data available. Nevertheless, with the growing interest to develop deep geothermal projects – which boomed after the amendment of the Mining Law in March 2023 – the need to get data available in a quick and effective way became evident. To meet this demand, it was decided to prepare different types of data packages that project developers can use via a data room service.

As the greening of district heating and residential heat is one of the top priorities of Hungary's energy strategy, the compilation of data packages focused on potential areas suitable for such developments. To get an objective and comprehensive list of potential sites, first an independent indicator system has been established. To have a successful (direct use) geothermal project, the most important, yet not the only requirement is to discover a suitable reservoir that provides the necessary temperature and yield to feed the future heating plant. As heat cannot be transported on long distances, it is of ultimate importance to have an adequate heat market nearby to the source as well. This factor is unfortunately often neglected or underestimated, leading to situations where a successful well drilled at excessive costs discharges large amounts of hot water in the middle of uninhabited areas for no use. Finally, the level of geological knowledge of a future exploration area matters a lot. Dense data coverage minimizes the geological risk and only reinterpretation of some old data might be necessary, whilst a wildcat drilling holds significant risks, which can be reduced by pre-drilling surface exploration (e.g. new seismic measurements).

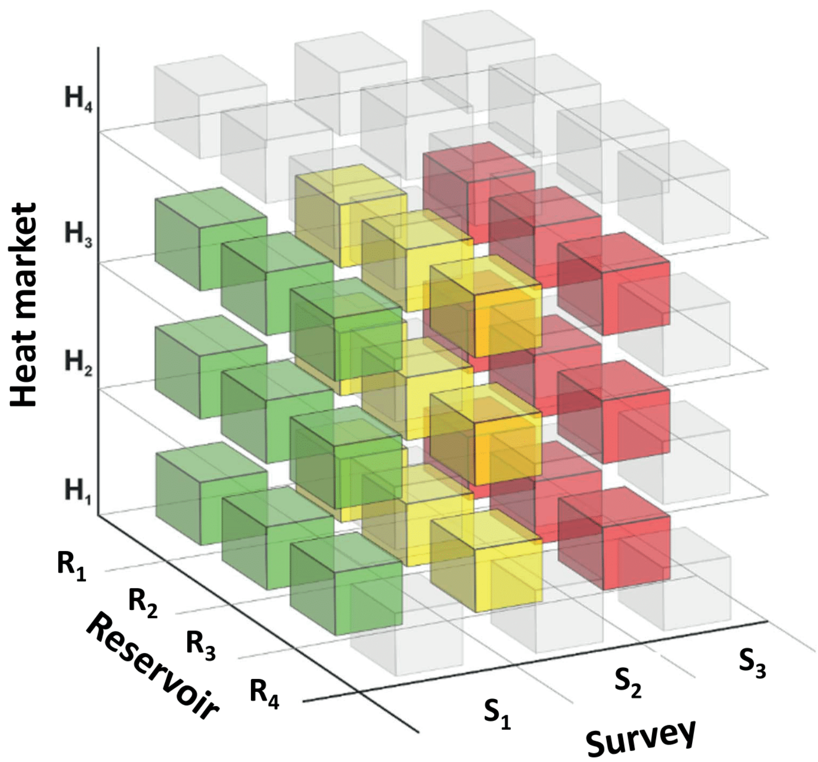

Figure 1: Indicator system to classify cities for future exploration. For a description and explanation of codes, please refer to the text.

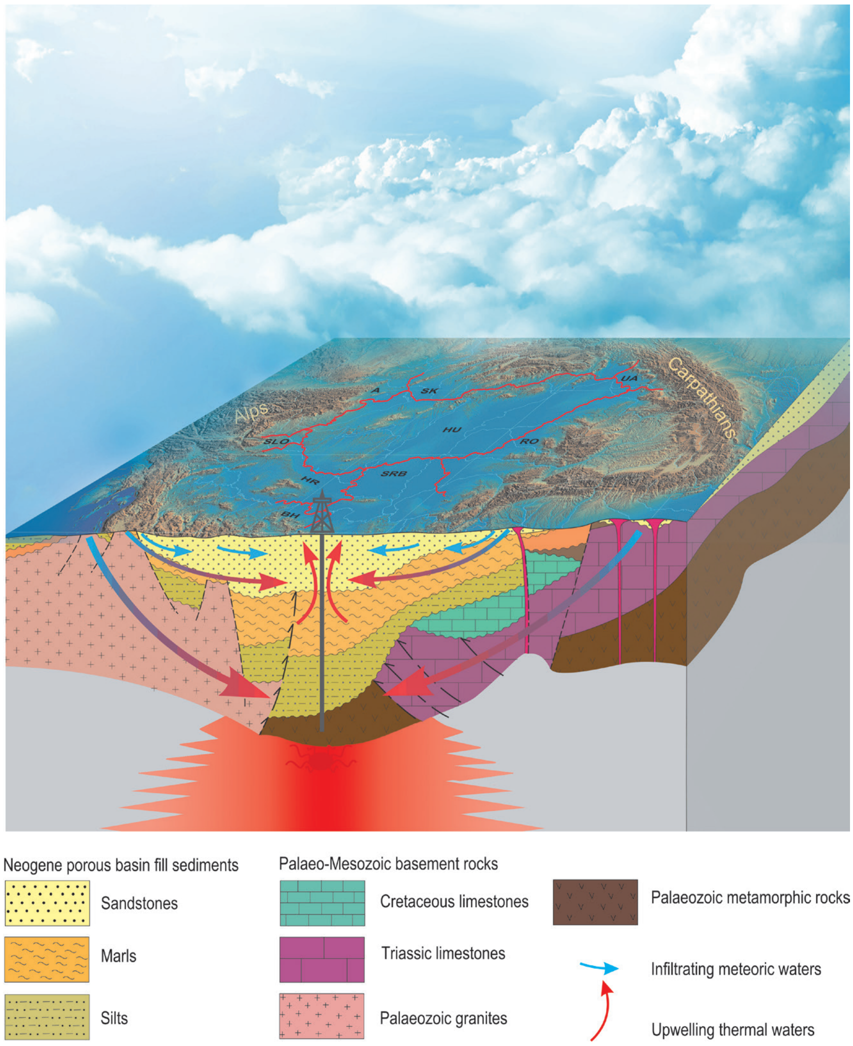

Figure 2: Theoretical model of the Pannonian basin with the main porous basin fill and fractured-karstified basement reservoir rock types and thermal water flow systems.

To encompass all these factors that have primary role on a successful geothermal project development, a numerical indicator system has been established that typifies future project sites (in the Hungarian case these are cities and their 15 km radius) assessing the type of geothermal reservoirs that defines the basic geological parameters of a future project (R), the heat market conditions (H), and the rate of surveillance (S). Using this system, each future project site can be characterised by a numerical code of 3 digits (Rx, Hx, Sx) (Fig 1).

R classes -Reservoir types

Given the geology and geothermal conditions of Hungary [4] [5], there are 2 main types of geothermal reservoirs with different characteristics (Fig. 2).

The majority and most well-known porous geothermal aquifers are represented by few tens to hundred m thick regionally extended and hydraulically interconnected sand bodies that deposited during shelf progradation, which represents the latest stages of the filling up of the Pannonian basin during the Late Miocene and Pliocene [6]. The best reservoirs are found at depths from 500 to 2000 m, where the temperature ranges from 40 to 110 °C [7], [8]. These porous “basin fill” reservoirs are widely used for direct use purposes, mostly in agriculture (greenhouse heating) and space / district heating. As these geothermal aquifers are widespread and explored by hundreds of active thermal water wells, the exploration risk is relatively low. Nevertheless, many of these reservoirs are already overexploited, characterized by decreasing piezometric levels due to high abstraction rates and insufficient reinjection.

The other major type of geothermal reservoirs is represented by different types of carbonates and crystalline rocks, such as limestones, dolomites, granites of Palaeozoic and Mesozoic age that form the basement of the Pannonian basin beneath the thick Neogene sedimentary sequences. They have an extremely complex structural pattern, arranged into nappes along thrust sheets, dissected by strike-slip and normal faults, associated with the multi-phase tectonic development of the Pannonian basin [9], [10]. These tectonic zones are important targets of geothermal exploration, as they represent regions with significantly increased permeability. The other valuable exploration target comprises basement carbonates that karstified during their geological evolution, thus possessed an increased secondary porosity as well. At the basement depth (around -2000 m or more) temperature can exceed 100–150 °C [11]. The coupled high temperature and high permeability makes these basement rocks excellent and prosperous reservoirs for larger scale district heating, or even combined heat and power projects which require higher capacities. Nevertheless, the exploration risks are much higher compared to the above lying porous basin fill reservoirs, as the discovery of the spatially limited fracture/karstic zones requires sophisticated subsurface models and geophysical exploration methods (mostly 2-3D seismic reflections).

Considering the above brief reservoir characterisation, the following classes have been identified:

- R1 – porous;
- R2 – karstic;
- R3 – fractured crystalline;
- R4 – not suitable (uplifted areas).

H classes - Heat market conditions

As it was highlighted before, matching the source with demand is the key for a successful geothermal project. Assessing heat market conditions, the following categories were defined:

- H1 – Cities with existing district heating infrastructure (sub-categories defined according to installed capacity: above, and below $10MW_{th}$);
- H2 – Significant industrial heat market;
- H3 – Settlements with considerable residential heat market (sub-categories defined according to population:

above 15 000 and between 10 000 and 15 000);
- H4 – No / insignificant heat market.

S classes – Surveillance

The probability of success of a drilling (i.e., that it hits the target reservoir rock with expected temperature and yield) can be significantly increased by raising the level of geological knowledge of the subsurface. Thus, the rate of exploration pre-determines the success of the project. Therefore, the following categories were defined:

- S1 – A well explored area, no additional data is necessary; the future drilling site can be located based on existing data and knowledge;
- S2 – A well explored area, however reinterpretation of old data is necessary to increase the consistency of the geological model;
- S3 – Underexplored area, new measurements are necessary to set up a trustworthy geological model.

3. Discussion

It is important to note that the different R-H-S classes do not imply any "quality" assessment, simply they characterize the given settlement and its surroundings as a future project site. Thus, the list of settlements can be adaptably modified at any time by applying different screening categories according to different strategic priorities. The numerical coding makes easy to list settlements in an objective way to answer multiple questions, e.g.:

1. Which are the cities, where the switching of district heating to geothermal is feasible with potentials for high yields and temperatures and moderate exploration costs (H1, R2, S2);
2. Where are significant industrial heat demands, whereas the project developer is ready to take higher risks and invest into exploration (H2, R1-3, S3);
3. Where are smaller settlements suitable for lower temperature town heating systems, where no extra survey is necessary (H3, F1, S1);

Applying the above-described classification scheme in Hungary, altogether 158 settlements and their surroundings were classified as potential targets for geothermal developments.

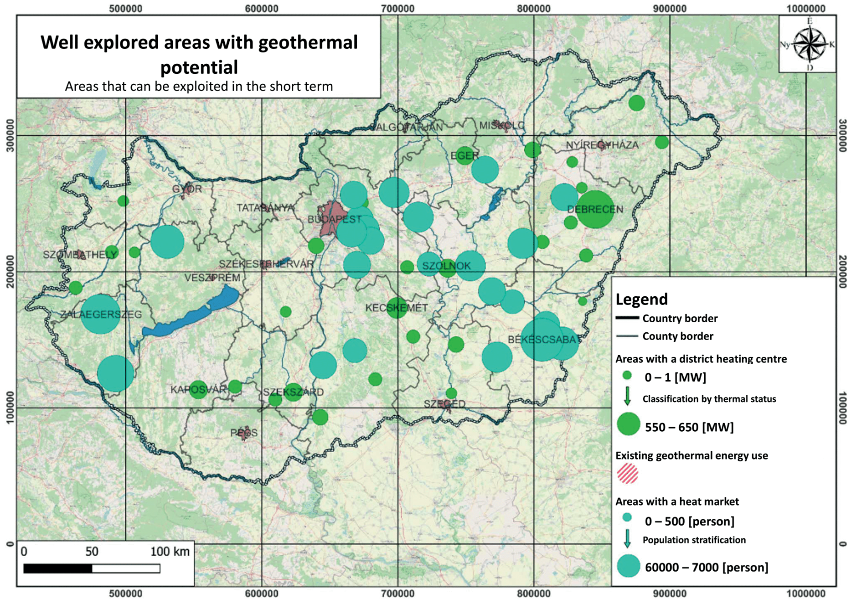

Figure 3: Geothermally prospective (R1, R2, R3) and well explored areas (S1) with existing heat demand (H1, H2, H3).

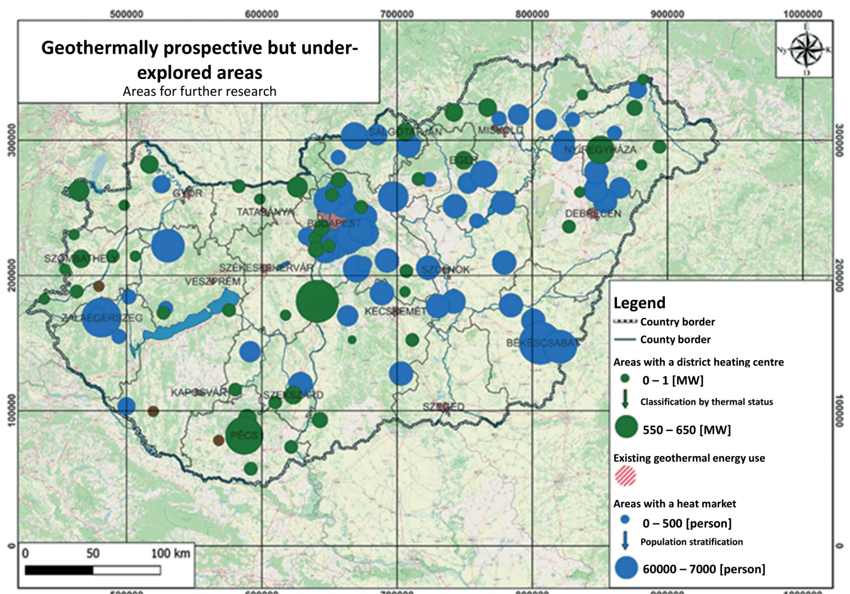

Figure 4: Geothermally prospective (R1, R2, R3), but under explored areas (S2, S3) with existing heat demand (H1, H2, H3).

Some screening results as examples are shown on Figures 3 and 4.

The classification system also allows for the identification of potential areas with existing heat demand, where additional research is needed to increase the knowledge of the subsurface, in other words to reduce the risk of unsuccessful drilling. In many cases the potential investors (e.g., smaller municipalities) do not have adequate resources to perform this pre-drilling exploration, which impedes project development. Nevertheless, if such focussed research is considered as a geological responsibility of the state, and exploration survey data are available for the public, it increases the willingness to invest into geothermal. This has happened in Hungary, where state financed seismic campaigns are ongoing (field surveys and interpretation) on areas where little/no data is available (S3) to increase the knowledge of the subsurface, thus make the areas stimulating future project developments.

The above discussed classification system also provided the basis for determining the list of settlements, for which so called data packages are being compiled that will be available through a

Table 1: Content and data type of OGRE and the data packages. Y/N refers to data availability: Y- such data included and N- such data not included.

	OGRE	Basic data package	Advanced data package
Basic info			
Location, basic topo map	N	Y	Y
Nature protection areas	N	Y	Y
Exploration (metdata)			
Hydrocarbonexploration area, mining plot	N	Y	Y
Geothermal protection zone	Y	Y	Y
Reports	N	Y	Y
CH well documentation	N	Y	Y
Borehole locations	Y	Y	Y
Geophysical exploration (2-3D seismic, magnetolellurics, gravimetry)	Y	Y	Y
Geology, geophysics			
Boreholes (lithostratigraphy)	N	Y	Y
Hydrogeological well documentattion	N	Y	Y
Hydrocarbon well book	N	Y	Y
Well logs	N	Y	Y
Geological horizons	Y	Y	Y
Geological 3D model, reinterpreted geological horizons	N	N	Y
Other thematic maps (e.g. tectonics)	N	N	Y
2-3D seismics (measured and interpreted)	N	Y	Y
Geological cross sections	N	Y	Y
Subsurface temperature maps	Y	Y	Y
Geothermal data (heatflux, heat conductivity, geothermal gradient, etc.)	N	Y	Y
3D subsurface temperature model	N	N	Y
List of relevant publications	N	Y	Y
Hydrogeology			
Thermal water well basic data (yield, temperature, screened intervals, utilization)	Y	Y	Y
Thermal water well hydrgeochemisrty (TDS, water type, CH4 content)	Y	Y	Y
Water level in wells (basic and operational)	N	Y	Y
Characterisation of thermal aquifers	N	N	Y

Geothermal Data Room opening in 2023 Q4. There are 2 types of data packages:

1. Basic data packages compiled for all prosperous 158 areas that contain a systematically arranged geological, hydrogeological, and geothermal data.
2. Advanced data packages that also contain reinterpreted data and expert assessments.

The content of the different types of data packages, as well as data available through OGRE are summarised in Table 1.

4. Conclusions

Making reliable and up-to-date geoscientific data publicly available is considered a geological responsibility of the state in many European countries and is often a decisive task of national geological surveys. Tailor-made databases of basic and reinterpreted data make possible to better delineate potential geothermal reservoirs and understand their properties, thus it is an important tool to de-risk geothermal project development. The presented Hungarian case introduced successive steps of public data service. The web-map based online geothermal information system (OGRE) provides a large-scale overview about the geothermal conditions of the country. Based on a set of geological and geothermal maps, it is possible to delineate prosperous areas for future exploration, where metadata of the available boreholes, geophysical measurements, hydrogeological data, etc. are also available. As a subsequent step, potential locations within these favourable areas have been categorised according to 3 criteria (reservoir type, heat market and rate of surveillance) and data themselves have been organised into data packages, which will be available through a data room service in the near future.

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Geological policy in Spain

*Manuel Regueiro y González-Barros [1, *]*

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Since 2015, the Spanish Official Professional Association of Geologists (Ilustre Colegio Oficial de Geólogos (ICOG)) has consistently presented comprehensive geological policy documents to various political parties and administrations, during national or autonomous communities' elections. On numerous occasions, the political parties have been invited to the ICOG's Headquarters in Madrid or to autonomous delegations to engage in seminars and discussions with ICOG members regarding these proposals. Over the previous decade, the list of proposals has been regularly updated to align with the evolving needs of society. This paper focuses on the 2023 version of the proposal, which, even though centred on Spain, can potentially serve as a valuable framework for proposals in any other country.

Depuis 2015, l'Association professionnelle officielle espagnole des géologues (Ilustre Colegio Oficial de Geólogos (ICOG)) présente systématiquement des documents complets de politique géologique à divers partis politiques et administrations, lors des élections nationales ou des communautés autonomes. À de nombreuses reprises, les partis politiques ont été invités au siège de l'ICOG à Madrid ou dans des délégations autonomes pour participer à des séminaires et à des discussions avec les membres de l'ICOG concernant ces propositions. Au cours de la décennie précédente, la liste des propositions a été régulièrement mise à jour pour s'adapter à l'évolution des besoins de la société. Cet article se concentre sur la version 2023 de la proposition qui, bien que centrée sur l'Espagne, peut potentiellement servir de base pour des propositions dans n'importe quel autre pays.

Desde 2015, el Ilustre Colegio Oficial de Geólogos (ICOG) de España ha presentado de manera constante documentos exhaustivos de política geológica a varios partidos políticos y administraciones, tanto en elecciones nacionales como en las comunidades autónomas. En numerosas ocasiones, se ha invitado a los partidos políticos a la sede del ICOG en Madrid o a delegaciones autónomas para participar en seminarios y discusiones con miembros del ICOG sobre estas propuestas. A lo largo de la última década, la lista de propuestas se ha actualizado periódicamente para alinearse con las cambiantes necesidades de la sociedad. Este documento se centra en la versión de 2023 de la propuesta, que, aunque se centra en España, puede servir potencialmente como un marco valioso para propuestas en cualquier otro país.

1. Introduction

The 2023 document, titled "27 Proposals for a national geological policy in service of citizens" [1] presents a detailed text that organises the proposals into the following chapters:

1. Education and Universities
2. Risk management and climate change
3. Infrastructure and land planning
4. Environment and sustainable development
5. Exploration and exploitation of natural resources
6. Energy policy
7. Public administrations.

[1] Spanish Official Association of Professional Geologists
* m.regueiro@gmail.com

This document has been forwarded to all the political parties participating in the recent general elections and has garnered acknowledgment from some of them. The primary objective of the proposals is to raise awareness among Spanish politicians about the significance of geology in the daily lives of all citizens and to provide specific solutions to the problems that geology can address when it is appropriately understood and applied by the government authorities.

2. Education and Universities

2.1. Inclusion of geological sciences as a mandatory subject in secondary education and high school

In Secondary Education, Biology and Geology should equip students with essential knowledge and skills to foster scientific literacy and enabling them to become active contributors to shaping their environment and understanding the consequences of their actions. This includes familiarity with significant scientific theories like plate tectonics, cell theory, and evolution. Moreover, the curriculum should cover ecosystems, trophic relationships, organism-environment interactions, and their impact on ecosystem dynamics. Unfortunately, in Spain, the study of this subject in the 4th year of Compulsory Secondary Education (Enseñanza Secundaria Obligatoria (ESO)) is currently optional, leading to a gap in geoscientific knowledge among students. To address this, it is crucial to incorporate more mandatory geological content in both ESO and High School. Without a solid foundation in geoscience, students may struggle to grasp the concept of sustainability, engage in collective challenges, and pursue careers in Earth sciences, which could potentially impede innovation and progress in this field.

2.1. Creation of a professional access master's degree

In Spain, university degrees have been adapted to comply to the Bologna Process, resulting in shorter study plans. Therefore, for geology studies, the undergraduate degree may not provide sufficient knowledge for professional practice. The legal sector provides an illustrative example of where this concern is addressed, where reforms ensure that lawyers and solicitors possess both theoretical and practical knowledge to safeguard citizens' rights and freedoms. A similar model for the geological sector, already in place in many European countries, is recommended as the best way to ensure quality in professions, where individuals' safety and property are at stake. This model bears resemblance to the system for selecting secondary education teachers, which entails a competitive exam, approval by the school community through specific training, a one-year public school assignment (unless they have prior teaching experience), and a final examination before an examination board. For the profession of geologists, the proposed model is based on the following stages:

1. Bachelor's degree: Responsibility of the universities;
2. Master's degree: Shared responsibility of universities, professional associations, and companies;
3. Internships: Responsibility of professional associations and companies;
4. Training courses by universities and professional training schools of the professional associations, in accordance with the regulations governing official postgraduate university education, as established in Law 34/2006, of October 30 [2], regarding access to the professions of Lawyer and Solicitor of the Courts.

3. Risk management and climate change

3.1. Basic law on land planning and natural hazard maps

Given the increasing occupation of land, frequently in an unregulated manner, and the requirement to develop natural hazards maps as stipulated in Article 15 of the Spanish Land Law [3], it is necessary to draft and approve a Basic Law on Land Planning. This should, serve as a universally applicable foundational regulation, without interfering with regional competencies, while also encompassing the development of Natural Risk Prevention Plans by the Autonomous Communities. This is crucial for ensuring proper land planning.

3.2. Improvement of flood risk prevention

Due to its geographical characteristics and river regime, Spain is a country with a high risk of flooding. According to a published study by the Geological Survey of Spain (Instituto Geológico y Minero de España (IGME)) [4] on natural hazards, the potential losses from hazards for the period 1986-2016 amounted to 29.5 billion euros, with 56% of those losses attributed to floods. The same study identifies Andalusia as the most dangerous area with a 22.5% risk of flooding, followed by the Valencian Community with 19.6% and Catalonia with 18.6%. Since flooding is a considerable geological risk that annually causes the most damage in Spain and Europe, structural measures need to be taken to effectively apply Article 11.2 of the Spanish Water Law 29/1985 [5] with the general principle of adapting urban land uses based on natural hazards maps. The proposed measures are:

- Adopting an insurance policy that responds to real risk.
- Implementing a policy of compensation for expropriations.
- Investing in flood control structures, such as flood attenuation reservoirs or channelisation, even if they are costly or have reasonable environmental impact.

Climate change will escalate these catastrophic hydrological processes. Investing in the actions stated above will be the only way to increase resilience. Conversely, neglecting to apply expert knowledge when urbanising will result in greater economic and social costs.

3.3. Improvement of volcanic hazard prevention

The Canary Islands are the only region in Spain with a high volcanic hazard, with recent registered activity on the islands of La Palma, Tenerife, El Hierro, and Lanzarote. It is recommended to streamline the procedures for the establishing a Volcanological Institute. This institute would serve as an observatory dedicated to the study and research of volcanic activity, centralising the efforts of various administrations.

3.4. Improvement of seismic hazard prevention

Regions in Spain with the highest seismic activity, include the southern part of the Iberian Peninsula and some areas in the Pyrenees. These areas require strict enforcement of regulations and oversight by public administrations. The nation needs to update and enhance its seismic-resistant regulations considering scientific and technological advancements and a more comprehensive understanding of seismic risks. Despite the urgency highlighted by the 2011 Lorca earthquake, national seismic-resistant regulations remain outdated in terms of hazard maps, application criteria, and the importance of the "soil factor" in amplifying damage. While earthquakes cannot be predicted, proactive measures can be taken to minimise damage and casualties. Spain should establish a comprehensive plan to prevent seismic risks, which involve implementing preventive measures based on seismic hazard and vulnerability studies, especially in high-risk areas. Methodological guidelines for natural risk prevention must be developed and widely disseminated to ensure their application by various authorities and the general population. Although Spain has advanced legislation in place, its real and effective implementation lags. In 2008, the ICOG (Spanish Official Association of Professional Geologists) collaborated with The Ministry of Housing to produce a "*Methodological Guide for the Development of Natural Hazards Maps in Spain*" [6].

3.5. Prevention of radon inhalation risk

Radon gas poses a potential threat in certain areas of Spain, including Madrid, Castilla-León, Extremadura, and Galicia, particularly in regions with a predominantly granitic geological substrate. Radon, an odourless and invisible gas, is created through the natural decay of radium and uranium in soil and rocks, accumulating indoors over time. High levels of radon in homes can significantly harm health, increasing the risk of lung cancer by up to sevenfold and contributing to 3% to 14% of lung cancer cases worldwide, according to the World Health Organization (***https://www.who.int/news-room/fact-sheets/detail/radon-and-health***). Smokers face an even higher risk, with a 67-fold increase in probability. Several factors influence radon concentration in homes, including soil type, porosity, permeability, and construction materials. Certain construction materials and building features can allow radon to enter buildings. Therefore, it is crucial for General Urban Plans to conduct local studies on radon emissions risks in homes to incorporate risk considerations in new constructions and recommend necessary rehabilitation measures for existing buildings. Notably, the Spanish Building Code (SBC) has recently introduced a new section DB-HS 6 Radon Protection.

3.6. Reduction of subsidence hazards

Spain faces a significant risk of subsidence, primarily due to the presence of soluble materials in its subsurface, which can lead to gradual or sudden land sinking. This risk is influenced by climatic conditions and subsurface materials, with limestone and evaporite-rich areas being particularly vulnerable. Karst processes can develop underground, often remaining hidden until cavities and collapses reach the surface. Spain's Cenozoic basins, such as the Ebro and Duero basins, the Tajo fault, and the Guadalquivir basin, contain substantial quantities of highly soluble salts, causing geotechnical issues in many cities. Approximately 7% of Spain's national territory is characterised by outcrops of evaporitic units, [7] and in other areas, these units are found at shallow depths beneath non-soluble alluvial and colluvial deposits. To address this unique risk, it is crucial to integrate various study methodologies, including historical and geomorphological perspectives on karst risk, the incorporation of geological and geotechnical data into risk maps, prevention plans, and urban planning. Additionally, predictive tools are needed to assess susceptibility and temporal evolution of these processes, particularly when dealing with highly soluble salts. Without preventive action, the impacts of climate change, such as declining groundwater levels, could result in significant economic and social costs.

3.7. Improvement of response mechanisms to natural disasters

Although notable progress has been made in the field of Civil Protection, we consider it necessary to continue promoting prevention and planning mechanisms for disasters. Natural hazard maps provide a competitive advantage in emergency planning processes for earthquakes, floods, landslides, volcanic eruptions, tsunamis, or coastal risks. The role of this discipline in early detection and warning processes for these phenomena is also important. This would enhance emergency management by establishing more efficient action protocols and integrating all available resources and scientific knowledge through the Operational Coordination Centres. Additionally, the training of personnel should be improved to provide higher quality citizen assistance and enhance the overall operation.

Public education is also crucial in prevention efforts. Education focussed on prevention, as well as creating a broader culture and awareness of safety within individuals and institutions, is fundamental in effectively managing natural risks.

4. Infrastructures and land planning

4.1. Development and implementation of a geological mapping plan

The approval of Law 14/2010, of July 5th, on Infrastructures and Geographic Information Services in Spain (Ley de Infraestructuras y Servicios de Información Geográfica de España (LISIGE)) [8], marked the first time in history that Geological Cartography was included as one of the official cartographies in Spain. This implies the obligation for administrations to update and maintain it. Currently, cartographic activities of this nature are registered by the Geological Survey of Spain (IGME) in the National Cartographic System. With the integration of IGME into the Spanish National Research Council (Consejo Superior de Investigaciones Científicas (CSIC)), there is a need to establish an organisation responsible for developing the Geological Cartography Plan within the framework of the National Cartographic Plan (Plan Cartográfico Nacional (PCN)). The PCN is an instrument approved every four years by the Council of Ministers and should be adequately funded for the update and maintenance of National Geological Cartography, which currently lacks an executing body.

4.2. Creation of an observatory for general urban planning and a reference centre for natural hazards

The increase in damages from natural hazards is primarily due to the growing population exposed to them, making it crucial to incorporate these phenomena into all territorial planning instruments. Compliance with the Spanish Land Law, as outlined in Royal Legislative Decree 2/2008 [3] is essential. This law mandates that urban development undergo prior environmental assessment and sustainability reports, including natural hazard maps. However, a recent study (by ICOG) identified deficiencies in compliance, with only 7.5% of Spanish municipalities with high natural risks adhering to these requirements.

To address this issue, it is recommended that all municipalities fall under the jurisdiction of the responsible ministry to ensure compliance with the legal requirement for natural hazard maps. A Technical Regulation for the development of these maps should be urgently enacted, incorporating guidelines from the Methodological Guide for Natural Risk Maps. Establishing a Sectorial Conference on Urban Planning is important for collaboration between the State and Autonomous Communities in preparing this cartography. Additionally, geological-geotechnical, hydrogeological, and natural risk studies should be integrated into various planning figures, considering current regulations.

In response to the challenges posed by climate change, the establishment of a Natural Hazards Reference Centre is proposed to monitor, analyse, and disseminate information related to economic, social, and environmental aspects of natural hazards. This centre could be attached to the Geological Survey of Spain (IGME), which currently serves as the national reference centre for natural hazards within the European Environment Agency framework.

4.3. Mandatory approval and registration of geotechnical studies in building construction

According to the available data, the requirement for registration and approval in the corresponding professional body of geotechnical studies for building projects, resulted in a reduction of incidents and accidents. However, since its abolition by Royal Decree 1000/2010 [9], dated the 5th of August, such incidents have increased, negatively affecting public safety.

It is thus proposed to reinstate the mandatory registration in the professional body of all geotechnical studies in building construction, as previously outlined in Chapter 3 of the Basic Structural Document Foundations (Documento Básico Estructural Cimentaciones (DBE_C)) of the Technical Building Code (Código Técnico de la Edificación (CTE)) (Annex 1) [10]. Furthermore, given the existing challenges and the expiration of the review period stipulated in Royal Decree 1000/2000, which eliminated the mandatory registration by professional associations, we believe it is necessary to promote the update of the list of professional works subject to mandatory approval, as specified in Article 2 of the decree. This update should clearly include geotechnical studies for building construction within this requirement.

4.4. Reform of the basic documents of the technical building code and the general regulation of the public procurement law

The Technical Building Code (CTE) [10] undergoes regular reviews every five years to incorporate technological advancements and ensure regulatory compliance. However, it is essential to revise the CTE to mandate geotechnical studies for all types of buildings. This also includes self-built single-family homes, regardless of whether they require ten-year structural damage insurance. Additionally, these geotechnical studies should be subject to control by the Technical Control Organisation (Organización de Control Técnico (OCT)).

Currently, geological and geotechnical studies, crucial for proper infrastructure planning, are often presented as annexes within civil engineering projects and are not adequately emphasised. They lack binding and contractual significance, making them susceptible to budget cuts. To address this issue, it is proposed that the General Regulation of the Law on Public Procurement Contracts, which is outdated, be reformed. Mandatory geological and geotechnical studies should be independently tendered and contracted before final project design, with allocated financial resources and the responsibility of competent technicians. This approach aims to prevent cost overruns, deviations, and project issues that can have economic and social consequences.

5. Environment and sustainable development

5.1. Groundwater protection plan against contamination

To prioritise water protection, there is a need for increased economic and human resources, aligning with European environmental policy goals. This policy emphasises safeguarding all types of water bodies, including surface, groundwater, transitional, and coastal waters. Updating assessments of potential contamination sources and implementing measures to protect water for human consumption is essential. This entails defining and enforcing protection perimeters and safeguard zones, integrating these measures into planning instruments, and obtaining the necessary licenses from competent authorities in land management, urban planning, and hydrological planning. Furthermore, professionalism among stakeholders involved in water abstraction and usage should be enhanced. Regulations, developed in collaboration with professional associations, should ensure that qualified professionals are responsible for activities like constructing and decommissioning abstractions. Additionally, any exploration or utilisation of water resources should require justification supported by a hydrogeological report signed by a competent technician.

5.2. Drought effects prevention

To effectively combat drought, the ICOG considers it crucial to adopt a holistic perspective on water within hydrographic basins. This entails detailed and constantly updated knowledge for water management, in order to understand the dynamics and characteristics of all stages of the local hydrological cycle. Special emphasis should be placed on the strategic role of groundwater and the combined use of groundwater and surface water to address both episodic and structural drought incidents.

5.3. Greater promotion of geothermal energy for the energy transition

Significant push is required for geothermal energy, given its high long-term value as a renewable energy source with consistent supply. A White Paper on Low-Enthalpy Geothermal Energy should serve as a basis for implementing policies with measurable indicators of generation and energy efficiency, fostering appropriate legislation, and providing financial support (subsidies or loans) for the development of geothermal energy in buildings.

Low-enthalpy geothermal energy for building heating and cooling, which are been successfully used in many European countries (such as Sweden, Austria, Switzerland, Germany, Italy, and Denmark), as well as in the United States and Japan, provides significant energy savings thanks to the significant development of geothermal heat pumps (GHP).

In Spain, the Basque Country, Catalonia, and Valencia are giving greater stimulus to the development of this type of energy. Essentially, it harnesses the heat accumulated in the ground as a result of solar radiation. The Earth absorbs and releases heat in a way that maintains a relatively homogeneous temperature in the shallow layers, between 5 and 100 meters deep, throughout the year. Geothermal energy represents savings of up to 80% compared to diesel and 70% compared to gas [11].

5.4. Research and development of H_2 and CO_2 storage technologies

In the coming years, it is crucial to prioritisze the development of H_2 (hydrogen) storage technologies to serve as energy reservoirs during periods of overproduction. This will ensure the ability to meet rising electricity demand during periods of low production. Additionally, advancements in carbon capture and storage (CCS) technologies are necessary to enable gas-fired power plants with their own CO_2 capture and storage mechanisms. This approach would allow for meeting electricity demand using fuels like methane found in coal beds with known reserves in Spain, while preventing CO_2 emissions into the atmosphere. These actions are imperative to address climate change and make fossil fuel-based energies more sustainable.

5.5. Research and exploitation of natural hydrogen reserves

Natural hydrogen will be a future fuel that guarantees sustainability for the system. The recent discovery of a significant natural hydrogen deposit in the province of Huesca (Spain) necessitates promoting exploration policies for this new resource, which is crucial in the energy transition.

5.6. Protection, use, and management of geological diversity (geodiversity) and geological heritage

These proposals have already been presented by the Geological Society of Spain and endorsed by the following national laws: Law 42/2007 of December 13 on Natural Heritage and Biodiversity [12], Law 5/2007 of April 3 on National Parks [13] and Law 45/2007 of December 13 on Sustainable Development of Rural Areas [14]. They are also supported by the derived regulations, among which the following stand out: Royal Decree 752/2010 of June 4 [15], the first program for sustainable rural development for the period 2010-2014; Royal Decree 556/2011 of April 20 [16], for the development of the Spanish Inventory of Natural Heritage and Biodiversity, and Royal Decree 1274/2011 of September 16 [17], the strategic plan for natural heritage and biodiversity for the period 2011-2017. The ICOG supports and defends them in their entirety:

1. The Ministry of Agriculture, Food and Environment must safeguard all-natural heritage: biotic and abiotic, including the conservation of geodiversity and its heritage in the same way as biodiversity;
2. Promote the development and compliance with legislative norms and initiatives, both national and international, aimed at the conservation and sustainable use of geodiversity and geological heritage, specifically: ensuring effective protection and conservation of geodiversity and geological heritage;
3. Promote public and private initiatives aimed at studying and cataloguing geological heritage, its conservation, and sustainable educational, outreach, and tourism use;
4. Natural heritage versus cultural heritage. In compliance with Law 42/2007, paleontological heritage is considered natural heritage and not cultural heritage and should be treated and managed accordingly by the competent administration;
5. Integration of geological heritage in the Environmental Impact Assessment (EIA) of projects;
6. Regulation of collecting, looting, and exploitation of geological sites.

6. Exploration and exploitation of natural resources

6.1. Legal changes for sustainable management of natural resources

The mining industry worldwide, and particularly in Spain, has undergone radical changes in recent decades. The current Mining Law, dating back to 1973 [18] and being pre-constitutional (the Spanish Constitution was approved in 1978), has become obsolete for the current reality. Therefore, it is necessary to develop a new Mining Law to address the new challenges of our mining industry (streamlined project processing, legal certainty, competition from other countries, ornamental rocks, quarry products, gravels and aggregates, carbon capture and storage, natural hydrogen, etc.).

The last Spanish Government proposed an Agenda for the Sustainable Exploitation of Natural Resources, which ICOG fully supports.

The fundamental pillars of this agenda were:

1. Geological and mining exploration by the Geological Survey of Spain (now under the Spanish National Research Council);
2. Adaptation of the pre-constitutional Mining Law to the state of the autonomous communities;
3. New regulation on Mining Safety;
4. Legal framework for the restoration of mining operations;
5. Improvement in mining statistics;
6. Review of the objectives of the Circular Spain 2030 for raw materials;
7. Utilisation of mining waste;
8. Rehabilitation of abandoned mining spaces and facilities;
9. Enhancement of mining cavities;
10. Improvement of the mining cadastre;
11. Statistical studies on the present and future supply and demand of mineral raw materials;
12. Analysis of critical raw materials for the Spanish industry;
13. Promotion of industrial value chains;
14. Improvement of mining productivity;
15. Circular economy;
16. Development of policies for good governance, transparency, ethics, and regulatory compliance;
17. Promotion of talent and employment with a gender equality perspective in the mining industry;
18. Enhancement of training;
19. Digitalisation;
20. Promotion of European industrial alliances;
21. Design of financial instruments to support the extractive industry;
22. Best available techniques for reducing environmental impact and emissions;
23. Recycling of waste;
24. Emission reduction;
25. Support for more sustainable processes;
26. Improvement of infrastructure;
27. Marketing and internationalisation of mining, auxiliary, and service companies;
28. Just transition;
29. Impact of mining on depopulated areas in Spain;
30. Support for research;
31. National Geothermal Research Plan (already developed by IDAE).

To streamline project processing in the mining sector, it is proposed that a new law or agenda should unify permit acquisition processes (mining and environmental) into a single procedure managed by a mining permit office. This office would handle all procedures and forward applications to relevant centres with the necessary competence. The new law should also establish principles of sustainable mining management, circular economy, and corporate social responsibility for mining companies, as well as clearly define the competencies of different stakeholders, including the state, autonomous communities, and municipalities.

In terms of exploration permits, the current maximum surface area is considered excessive, and a reduction to 600 mining grids is proposed. Definitions of resource types in the existing mining law and regulations need to be updated to align with current knowledge and technological advancements. It is suggested that low and very low enthalpy geothermal resources be excluded from mining legislation, focusing only on medium and high enthalpy resources that require drilling deeper than 200 meters. Additionally, it is recommended that areas with cancelled permits become open for registration automatically. Local communities with mining operations should receive additional benefits beyond those already established by law, similar to regulations for hydraulic fracturing projects.

Regarding professional competencies, we propose the repeal of the Complementary Technical Instructions of the General Regulation of Basic Mining Safety Standards as they limit professional competencies compared to the current law and its regulations. The suggestion is to base professional competencies on both academic training and professional experience, following a liberalising trend observed in the European Union and ensuring safety while allowing the market to determine qualified professionals for specific tasks.

6.2. Roadmap for a national mining policy

Spain lacks a comprehensive national mining policy that should align with the EU Raw Materials Initiative. The country holds significant mining potential that could enhance development, employment, and the national standard of living. To achieve this, a new Mining Law is required, along with adjustments to legislation concerning territorial planning and the environment. Territorial planning should prioritise mineral resource existence before land use decisions to prevent resource sterilisation. Municipal urban planning should include maps of mineral resources, prepared by the mining authority in collaboration with the Geological Survey of Spain, to guide future land use decisions. Comprehensive mining exploration plans are also essential, aligning objectives with national needs, including critical minerals for industry. Life cycle studies of materials and circular economy models should be conducted by the Geological Survey of Spain to understand these needs. Educational outreach programs about the importance of mineral resources should be integrated into schools and high schools as part of the mining policy. Additionally, enhancing the efficiency of mining exploration, exploitation, and production is crucial. A technological research plan in mining, led by the Geological Survey of Spain and funded by the relevant ministry, should strengthen research and technological development in the mining sector. Collaboration with industry stakeholders, following the European model, should be established. The primary objectives of the National Mining Policy should be to improve accessibility to national mineral resources for investors and promote their exploration and exploitation while ensuring sustainability and environmentally responsible practices.

6.3. Regulation of hydraulic fracturing and hydrocarbon prospecting

According to Article 8.1 of the Spanish Climate Change and Energy Transition Law [19] "*no new authorisations will be granted for activities related to the extraction of hydrocarbons that involve the use of high-volume hydraulic fracturing*." However, in order to create strategic reserves for emergency situations, exploration authorisations and research permits should be allowed based on social and economic interests or the absence of technological alternatives. National Defence and Public Security interests should also be considered. The ban, as demonstrated by the war in Ukraine, causes serious harm to the national industry, and hydraulic fracturing (fracking) should be authorised as long as it is executed based on the precautionary and preventive principles outlined in Article 191.2 of the Treaty on the Functioning of the European Union [20], through an appropriate Environmental Impact Assessment (EIA), in accordance with Legislative Royal Decree 1/2008 [21], of January 11, approving the consolidated text of the Environmental Impact Assessment Law for Projects, and Law 6/2010, of March 24 [22], amending the same, as well as the rest of the current regulations at the European, national, and regional levels that are applicable, in order to avoid any type of impact on people, property, and the environment.

Research and exploitation projects involving natural resources, like shale gas, require a specialised team of experts in natural environments and mining research. These experts should oversee drilling processes, monitor them effectively, and control any potential environmental consequences. It is crucial for Spain to expand its inventory of available resources, including shale gas, to make informed decisions about their exploitation based on economic and geopolitical factors. While delaying resource exploitation can be reasonable when circumstances permit, not knowing the extent of available resources can have significant consequences. To ensure energy supply and economic stability, studies should be conducted to facilitate decision-making.

ICOG advocates for balancing economic development and environmental protection. They emphasise that techniques promoting energy self-sufficiency should not be dismissed. The Spanish state should regulate the exploitation of unconventional hydrocarbons like hydraulic fracturing within its competencies, considering strategic environmental planning, the unconventional nature of the technique, and environmental limitations. Exploration and research permit for hydrocarbons should be allowed to create strategic reserves. Spain's high energy dependence on imported oil and gas underscores the importance of investigating indications for finding oil traps within the country through controlled drilling, including offshore exploration. A comprehensive State Pact is proposed among political groups and social actors to reduce Spain's energy dependence, emphasising the reconciliation of economic development and environmental protection. The debate should not be limited to "prospecting yes or no," as it is essential to protect both economic development and the environment.

7. Energy policy

7.1. Radioactive waste law

Extending the lifespan of nuclear power plants necessitates updated geological risk studies, particularly considering climate change-related phenomena like droughts and floods. However, the foremost concern is the management of radioactive waste, for which a definitive solution is lacking. Establishing a stable regulatory framework is crucial to construct a Deep Geological Repository (DGR), preceded by an underground laboratory. The Centralised Temporary Storage (CTS) project serves as an interim, time-limited stage with a focus on research and development (R&D). During this phase, underground facilities are essential. A long-term National Energy Plan, agreed upon by different political parties, is necessary for economic investments and nuclear site safety. Shifting energy policies can impede investments and negatively impact nuclear safety. Quality-assured site characterisation studies are emphasised, and their results should inform decision-making processes, as geological and geotechnical risks can render nuclear facility safety unfeasible.

8. Public administrations

8.1. Law on services and professional associations: professional statute

A new Law on Services and Professional Associations is necessary, aligning with Article 36 of the Spanish Constitution. This law should harmonise the responsibilities of various regulated professions at the national level, assigning shared duties when needed to promote equal opportunities and a unified market for professional practice. The existing Law on Professional Associations from 1974 is outdated and requires comprehensive adaptation to the regulatory framework governing regulated professions. The new law should determine which professions require mandatory membership in professional associations. Given the significance of this issue in the service market, both nationally and within the European framework, it should be addressed in accordance with Community Law. The elimination of barriers to the free movement of people and services among EU Member States is a key objective of the European Community, as stated in Article 3.1.c of the Constitutive Treaty. This goal allows nationals of Member States to practice a profession in a different Member State from where they acquired their qualifications. To achieve this, the law should consider the primacy of the Professional Qualifications Directive 2005/36/EC [23], which relate to the recognition of professional qualifications. These directives provide a framework for mutual recognition of diplomas, certificates, and other qualifications. Spain has already incorporated Directive 2005/36/EC into its legislation through Royal Decree 1837/2008.

The development of a regulation governing the curriculum for science professions is necessary to effectively regulate these professions. Additionally, the Spanish Professional Union proposes the enactment of a Professional Statute to provide a clear and recognised definition of the concept of a profession, aiming to create a distinctive and identifiable category that values professional work. The Professional Statute would apply to all regulated professions, i.e., those that share the following essential principles:

1. Relevant/adequate qualifications given the provision of services of marked intellectual nature, as well as continuous training, continuous professional development, recognition and validation of professional competence;
2. Independence of professional judgment or professional autonomy in the context of professional practice, in any field of activity, including those based on public and private employment relationships;
3. Responsibility of the practicing professional as a result of their professional freedom to act according to their knowledge and conscience;
4. Control of professional practice by an independent, autonomous, and impartial body endowed with public powers to regulate the profession and carry out the ethical function;
5. Action based on the impact on the general interest/in the interest of the client, patient, or user, of quality and with a commitment to strict and precise respect for professional ethics and norms.

In these professions, a key aspect is the professional act, meaning that the practice of the profession directly or indirectly impacts those who use or benefit from the services provided, potentially affecting their fundamental rights. Due to this, every professional is required to adhere to ethical rules and be subject to oversight of their professional practice by an independent body. This oversight is based on the requirement of possessing an enabling degree and being a member of a professional association, which are essential elements mandated by the Spanish Constitution. This statute will revolve around the following main aspects:

1. General principles of professional practice. Autonomy, independence, good practice, continuous professional development, competence, registration of membership, incompatibilities, continuous training, principles of professional ethics, professional career;
2. Modalities of practice: public, private (freelance, corporate, ...), multidisciplinary teams, contracted, voluntary/volunteering, online services;
3. Control/Guarantee of professional practice. Ethical function, disciplinary authority, responsibility, liability insurance, service quality;
4. Obligations and rights. Fees, informed consent, professional engagement, data handling;
5. Advertising regulations;
6. Professional registry;
7. Relations with the administration;
8. International relations.

8.2. Creation of the national geological institute

The ICOG proposes the creation of a National Geological Institute with the rank of General Directorate, with the following functions:

- Development of the Geological Mapping Plan within the framework of the National Cartographic Plan (PCN), an instrument approved by the Council of Ministers every 4 years, endowed with the appropriate budget for the update and maintenance of the National Geological Mapping, which currently lacks an executing body.
- Integration of competencies in volcanic and seismic risks (including the seismic network of the National Geographic Institute (IGN)) into the National Geological Institute to facilitate the management of emergency situations and natural disasters, such as the Lorca earthquake or volcanic eruptions on the islands of La Palma or El Hierro.
- Integration of the competencies of the National Geological Institute of the extinct Geological Survey of Spain in the fields of Mining, Groundwater, Geological Hazards, and Geological Heritage.

A National Geological Institute operating like the United States Geological Survey (USGS), one of the most prestigious institutions in the world in the study of earthquakes and volcanic eruptions, and in the geological knowledge of the territory and its dissemination.

8.3. More geologists in the public sector

The ICOG criticises the limited presence of geology professionals in public administrations and highlights discrimination in public employment requirements. Many contracts in the public sector demand specific qualifications (usually civil or mining engineers) for certain roles, excluding geologists or geological engineers, even though they possess recognised competences and attributions according to Royal Decree 1378/2001 [25]. This restriction hinders access to economic activity, violating the principles of the Law 20/2013 on Guarantee of Market Unity [26].

To address this issue, there is a need for increased representation of new constitutional professions, like geologists, hydrogeologists, and others, in the staffing structures of public administrations. These professionals are crucial for the proper application of legislation, regulations, and projects related to natural sciences, ensuring sustainable development as demanded by citizens. Specialists in natural sciences should be present in the management bodies of protected natural spaces to uphold the proper application of Law 42/2007 on Natural Heritage and Biodiversity [10].

With the Technical Building Code [10] and the Land Law [3] in effect, housing and construction authorities require an adequate number of geotechnical specialists to develop technical regulations, ensure quality in geotechnical studies, and incorporate the latest technologies.
Equal opportunities must be guaranteed in professional practice, with decisions based on professional competences rather than arbitrary decisions by public corporations.

9. Conclusions

Geology is the science that studies the Earth and describes and interprets its composition, structure, evolution, and current dynamics. Throughout history, geology has always been an important factor in the economic, social, and cultural development of societies. In the 21st century, geology has a significant role to play in addressing contemporary challenges. It can and should contribute to meeting society's demands, including the supply of raw materials, the understanding and management of freshwater resources, the planning, design, and construction of civil works and buildings, the fight against climate change, and the promotion of clean energies, such as geothermal energy. Above all, there is a growing recognition for the importance of studying active geological processes and the associated risks they pose. These processes include: seismicity, volcanism, floods, landslides, subsidence, erosion, and more. They present real threats and cause numerous casualties and substantial damage to both people and infrastructure.

To address these challenges, a better-informed citizenry is needed, as citizen participation is already key in all policies that aim for sustainability. In this regard, we are concerned about the limited understanding of geology, as there is a lack of time in schools to explain the origins of everything around us. This basic deficiency has negative repercussions both on scientific culture and on the inability to understand the world from a global perspective. The absence of engaged and informed citizenry results in long-term negative effects and represents a waste of significant potential.

Our lives are intricately linked with planet Earth, and understanding its behaviour, offers us the opportunity to harness its resources and also shield ourselves from the perils of its natural processes. This knowledge allows us to avoid attributing accidents or natural disasters to nature or divine forces when scientific understanding of many of these threatening phenomena is accessible. The development and implementation of initiatives related to these contributions from applied geology and geological engineering will yield significant social and economic benefits for Spain.

This knowledge holds significant potential for economic development. For this reason, Spanish geologist members of the Spanish Official Professional Association of Geologists (ICOG), have compiled this document containing their contributions for the general elections. The purpose is to provide our country with a national geological policy for analysis, study, and evaluation by political parties. If deemed suitable, this policy should be included in their respective electoral programs.

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Legal protection of water sources and application of geoscientific principles in concession grants in Croatia

Ratko Vasiljević [1, *]

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The concession of water resources often leads to a public misunderstanding, with concerns raised about privatisation and threats to public water supply. These concerns are frequently expressed without a clear understanding that obtaining a concession for the exploitation of any water resource does not confer ownership rights, but rather grants the right to exploit defined quantities, along with accompanying obligations outlined in the concession contract. The distinction between ownership and concession is often overlooked by the public. This paper presents the application of the Croatian legislation in the process of obtaining a concession for the water use, with special emphasis on the principle of prioritising the use of water resources. Additionally, it highlights the significance of a geoscientific approach to characterise these water resources.

La concession des ressources en eau conduit souvent à un malentendu du public, avec des inquiétudes quant à la privatisation et aux menaces qui pèsent sur l'approvisionnement public en eau. Ces préoccupations sont souvent exprimées sans comprendre clairement que l'obtention d'une concession pour l'exploitation d'une ressource en eau ne confère pas de droits de propriété, mais accorde plutôt le droit d'exploiter des quantités définies, ainsi que les obligations correspondantes décrites dans le contrat de concession. La distinction entre propriété et concession est souvent négligée par le public. Cet article présente l'application de la législation croate dans le processus d'obtention d'une concession pour l'utilisation de l'eau, avec un accent particulier sur le principe de priorisation de l'utilisation des ressources en eau. De plus, il souligne l'importance d'une approche géoscientifique pour caractériser ces ressources en eau.

La concesión de recursos hídricos a menudo genera malentendidos públicos, con preocupaciones sobre la privatización y amenazas al suministro público de agua. Estas preocupaciones se expresan con frecuencia sin una comprensión clara de que obtener una concesión para la explotación de cualquier recurso hídrico no confiere derechos de propiedad, sino que otorga el derecho a explotar cantidades definidas, junto con las obligaciones correspondientes establecidas en el contrato de concesión. La distinción entre propiedad y concesión a menudo se pasa por alto por el público. Este artículo presenta la aplicación de la legislación croata en el proceso de obtener una concesión para el uso del agua, con especial énfasis en el principio de priorizar el uso de los recursos hídricos. Además, destaca la importancia de un enfoque geocientífico para caracterizar estos recursos hídricos.

1. Introduction

Water resources are indispensable and play a crucial role in the smooth functioning of society, and consequently municipalities and the state and that depend on it.

A few years ago, the public sphere was frequently filled with statements expressing concerns like, "*Water is a public good and what will happen to the public water supply when foreigners take control? Croatian water sources are being privatised, leading to a loss of national control over major sources of drinking water. Foreigners ownership is a threat. We should prohibit the sale of water resources. What about the public good after the sale of the water bottling companies with concessions? The Government is urged to intervene to safeguard national interests.*" The question arises, is there a justified reason for panic?

These statements result from the lack of understanding of legal practices and their application. It is crucial to recognise that, obtaining a concession for the exploitation of water resources, does not confer ownership, instead, it grants the right to exploit defined quantities, along with obligations outlined in the concession contract. The public often fails to distinguish between the concept of ownership and the concept of concession, leading to discussions on privatisation.

In reality, the company that "owns" the water source actually only holds exploitation rights in accordance with the conditions under which the concession was obtained. This paper addresses frequently asked questions, providing answers based on the current regulations in the Republic of Croatia. It emphasises the need for the public to differentiate between water used for municipal supply, water exploited for commercial purposes and water exploited for industrial and technological purposes.

Groundwater reserves for the Municipal water supply are evaluated in compliance with Article 100 of the Law on Waters - *Identification of water for human consumption*. To prioritise the use of water for water supply, the competent authority, Croatian Waters (Hrvatske vode), undertakes identifying all water sources

[1] Expert Witness For Mining, Geology and Petroleum Engineering in 2nd Mandatory, nominated by Ministry of Justice and Public Administration, Republic of Croatia
* rvcro@yahoo.co.uk.

for human consumption that deliver an average of more than 10 m³ of water per day or that supply more than 50 people. All such groundwater bodies are reserved for these purposes in future planning.

These groundwater bodies are eligible for concessions to commercially extract water for technological and similar needs, exceeding 10,000.00 m³ per year. Concessions may also be granted for the purpose of distributing water on the market in its original form, or in a processed form, such as bottling or other packaging.

The concession holder should be aware that the exploitation of water resources is subject to the Order of precedence by purpose in compliance with Article 96 of the Law on Water [14]. That implies that water supply for human consumption and sanitary needs, as well as for fire protection and defence, has priority over the use of water for other purposes. In situations where water shortages are so severe, that it becomes impossible to fulfil the needs of all users in a certain area, the restrictions on the use of water may be imposed concessionaires in accordance with Article 93 of the Law on Water.

Every company seeking concessions must conduct a hydrogeological study, based on surveys or other data, to assess the impact of the pumping on the water resources of the aquifer. This type of study should only be undertaken by a contractor (company) certified for such work, as stipulated in article 109, 110 of the Law on Water [14] and the accompanying Ordinance [22]. The Ordinance defines specific conditions that must be satisfied, particularly regarding technical equipment, the number of employees and their expertise.

There is no standardised methodology for assessing the impact of groundwater pumping on the aquifer due to variations in aquifer types (intergranular, confined, non-confined, aquifers in karst areas etc.), varying levels of knowledge and diverse histories of water exploitation. Consequently, the responsibility lies with the contractor who must demonstrate competence in compliance with regulations. The hydrogeological study should be approved by the competent authority, Croatian Waters, which grants permits (concessions) to water users.

This paper explains application of the Croatian legislation in the process of obtaining a concession for water usage, with a specific focus on the principle of prioritising the use of water resources. The geoscientific approach is particularly important for their characterisation of these sources.

This paper outlines the approach to obtaining a concession for groundwater pumping from the Zagreb Aquifer, with a focus on two locations. The first location is the Chromos factory at the eastern part of the city, and second location is a pharmaceutical factory, Pliva, located in the western part of the city. The emphasis will be on adhering to regulatory requirements throughout the application process.

Two distinct techniques were employed: an aquifer test for Location 1 and modelling for Location 2. The choice of technique was based on available data for each location.

2. Study area

The study areas encompass two locations situated on the Zagreb Aquifer. Location 1 is positioned in the eastern part, while Location 2 is situated in the western part.

Location 1 corresponds to a company named Chromos, located on the eastern part of the Zagreb aquifer. On-site, there is a well with a diameter of about 40 cm, from which water is drawn for the company's technological needs.

The water supply well was drilled to a depth of 15 meters, the diameter of the well is 40 cm (0.4 m), and the pump is installed at a depth of 10 m. The declared capacity of the pump is 1200 l/min (20 l/s), and the actual capacity measured during pumping was 15 l/s.

The depth from the surface to the groundwater level is approximately 7 m, and the thickness of the saturated part of the well is about 8 m. The well is perforated along its entire profile. The specified task was to demonstrate that the pumping of groundwater, in line with the declared capacity, would not adversely impact the hydrogeological conditions in the vicinity of the location.

The estimated thickness of the aquifer at the location is roughly 90 meters, comprising approximately 20 meters of alluvium and around 70 meters of lacustrine deposits [1].

Location 2 is a company named Pliva, located in the western part of the Zagreb aquifer. The company has submitted an application for a concession to pump 100,000 m³ of water per year.

Location 2, Pliva is located in the marginal area of the Zagreb aquifer, formed from proluvial deposits transported from the southern slopes of Medvednica by watercourses and erosion processes. To gain a get a better understanding of the interplay of the geological components, below is a description of the alluvial part that constitutes the Zagreb aquifer [2].

The hydrogeological studies for both locations assessed the sustainability of pumping specified quantities over the maximum period for which obtaining a concession is possible (30 years), in accordance with Regulation [3]. The locations are displayed in the figures (Figure 1 , Figure 2).

The Zagreb aquifer almost entirely

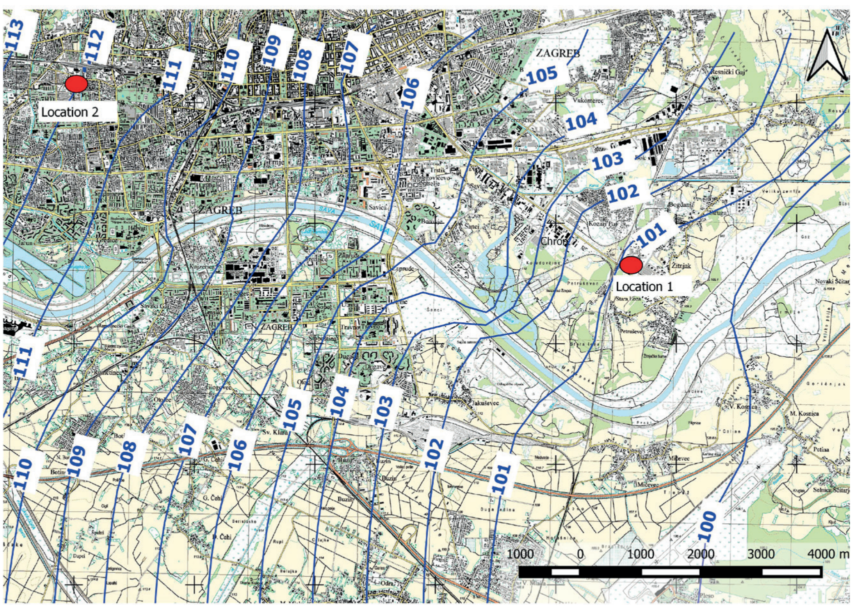

Figure 1: Locations 1 and 2 displayed on the topographic maps with hydro contours of groundwater (high groundwater level), modified [4].

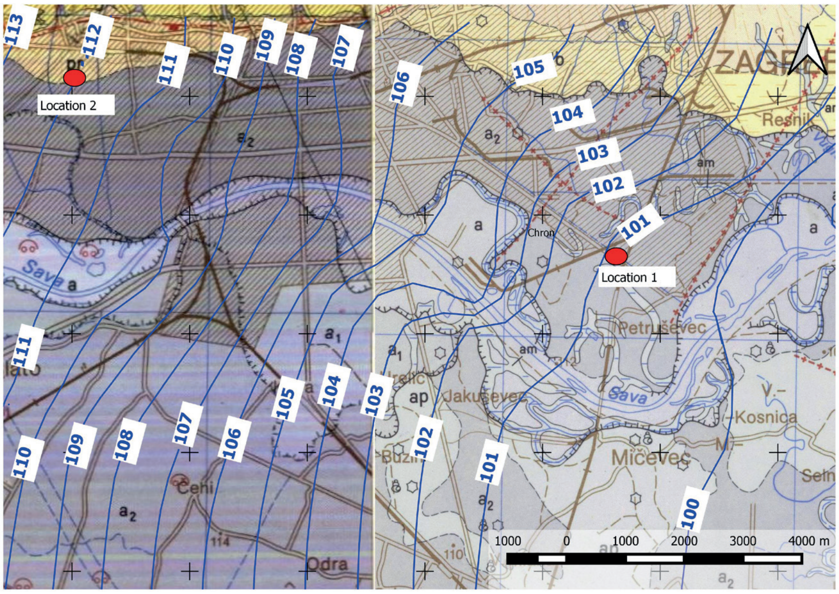

Figure 2: Locations 1 and 2 displayed on the geological map, modified [4 - 6].

consists of Quaternary deposits, predominantly deposited by the Sava River, with minor exceptions. Coarse gravels dominate in this composition. The geological relationships of the considered terrain are presented based on geological data from the Basic Geological Map, sheets Zagreb [5] and Ivanić Grad [6] along with associated interpreters [7 , 8]. According to this data, the oldest rocks that make up the Zagreb aquifer system are Pleistocene loess. Above them, deposits formed through the influence of surface flows, including those from the Sava River and its tributaries, as well as deposits of floodplains and swamps. Additionally, there are floodplain deposits created by the erosion of marginal parts of the surrounding mountains.

Plioquaternary (Pl,Q) deposits constitute the youngest Neogene and partially Pleistocene sediments, forming the lower sections of the Zagreb aquifer system in certain areas. In the marginal basin region, these deposits lie discordantly on various rocks of Tertiary, Mesozoic and Palaeozoic age. The Plioquaternary deposits were deposited in marginal zones of pre-existing lakes, with an assumed maximum thickness in the wider area reaching up to 150 m [7, 8].

Holocene Alluvium of the second Sava terrace (a_2): The second Sava terrace was developed with minor interruptions along the entire course of the Sava River in the wider research area. It was created by the River Sava cutting into older sediments. The second Sava terrace consists of an alternation of coarse-grained gravel and sand. The amount of sand compared to gravel increases from northwest to southeast, i.e., in the direction of the Sava River. The size of the sand grains decreases in the same direction. Due to intense erosion and significant influence from neotectonic movements, the thickness of the deposits on the second Sava terrace varies considerably [7, 8].

Alluvium of the first Sava terrace (a_1): After the deposition of gravel and sand that makes up the second Sava terrace, a phase of erosion and denudation occurred. The Sava cut into its own sediments, as was the case with the second and third terraces. In many places throughout the entire terrace, the old Sava riverbeds are visible. The thickness of the alluvial deposit of the first Sava terrace is usually 10-25 m, and in some places, it is known to be up to 45 m thick.

Alluvium of recent streams (a): Under this name, sediments in the area immediately adjacent to the Sava and stream alluvium deposits, formed by flooding during high water levels and floods. Predominantly composed of gravel and sand, the granulation of which varies greatly. The thickness of these deposits does not exceed 10 m.

Deluvian - proluvian (dpr): Deluvial - proluvial deposits are found in smaller quantities on the southern and western slopes of Medvednica. They are developed mainly in the form of coarse-grained slightly rounded pebbles, which are mixed with sand and clay. The thickness of these deposits is not known, but it is assumed to be ten meters [9 - 12].

3. Materials and methods

The methods employed in the study, included a review of legislation, pumping tests and modelling. Decision criteria were established based on their impact on hydro contours.

3.1. Review of legislative framework

Water resources are comprehensively addressed by all three levels of the Croatian legislation:

1. Fundamental law of the state - the Constitution of the Republic of Croatia [13];
2. Law on Water [14];
3. Regulation [3].

In the Republic of Croatia, in accordance with the principle of tripartition, laws are passed by the legislative government, the Croatian Parliament. On the other hand, regulations and ordinances are passed by the competent authorities, typically the ministries, which are the executive bodies. It is these competent authorities that are responsible for issuing concessions. According to Article 52 of the ***Constitution***, waters are of interest to the Republic of Croatia and have its special protection [13].

Law on Water defines how water can be used and exploited, the rights, fees and restrictions are also determined by the Law and regulations. Pursuant to Article 12, the public water resource is owned by the Republic of Croatia, it is inalienable, and no right of ownership can be exercised over it. Pursuant to Article 16, the public water resources are managed by the competent authority, Croatian Waters. The public water resource on which the spring with a minimum capacity of 10 m^3/day is located is managed by the public supplier of water services. From which it follows that public water supply services can only be provided by a public supplier. Therefore, according to the current Law on Water, "foreigners" cannot manage public water resources. According to Article 86, this includes the capture of water for the supply of drinking water and for placing it on the market in its original or processed form in bottles or other packaging. Furthermore, according to Article 87, individuals are granted the right to utilise water, provided it done so judiciously and economically. The usage should be safeguarded from waste and harmful alterations to its quality, while ensuring it does not impede the legal rights of other individuals to use water. As per article 96, the commercial use of water should not threaten the public water supply. The use of water to supply the population with water for human consumption and sanitary needs, for the purposes of fire protection and defence has priority over the use of water for other purposes. The total amount of water that can be exploited commercially is defined according to Article 102.

Capturing water for human consumption in its original form in an amount greater than 3,500,000 m^3 per year for the purpose of selling it on the markets of other countries is an activity of interest to the Republic of Croatia [14]. For example, Company Jamnica has a concession for pumping 280,000 m^3 per year, that is, almost 11 times less than the quantities prescribed by Article 102. For comparison, the Mala Mlaka municipal water pumping station in the City of Zagreb pumps about 5 m^3/s, meaning that every 15.5 hours it exhausts the amount of water equivalent to the annual concession for the source of Jamnica [15].

The commercial use of water is regulated by the ***Regulation*** [3]. According to Article 177 of the Regulation, a concession for the use of water is required for the capture of water for human consumption, for the purpose of placing it on the market in its original form or in a processed form, in bottles or other packaging. As for the regulation of public water supply, the right to use water for this purpose is governed by the water permit issued by Croatian Waters.

The concession is not granted for the performance of public water supply activities (Article 186 of the Regulation). Pursuant to Article 2 of the Regulation, a concession for capturing spring, mineral and thermo-mineral waters for marketing in original or processed form, in bottles or other packaging can be granted for a period of up to 30 years.

When obtaining a concession, it is necessary to pay a one-time fee for the concession (Article 4). The one-time fee is not defined, but for the extraction of spring, mineral and thermo-mineral waters for the purpose of placing them on the market in their original form, the one-time fee cannot be less than 50% of the amount of the annual fee (Article 6). This is determined by the amount of water for which the concession is granted, whereby the most favourable bidder is selected, in other words, the one offering the highest payment. Furthermore, throughout the concession period, as outlined in Article 5, the annual fee for capturing spring, mineral and thermo-mineral water for the purpose of placing it on the market in its original form is calculated based on the quantity of captured water. This fee stands at HRK 30.00/m^3 (approximately 4 EUR) [3]. For comparison, the cost of one cubic meter, inclusive of all charges for water supply, drainage, fees, etc., in Zagreb is just under HRK 20.00/m3 or slightly less than HRK 0.02/l (approximately 0.27 Euro Cents) [15].

The Croatian public often refers to the Constitution of the Republic of Slovenia in which, according to Article 70a, every individual has the right to drinking water. Water resources are a public good in state management and serve as a priority. Additionally, the sustainable supply of drinking water and water for households are not a marketable commodity [16]. The supply of drinking water and water for households is facilitated by the state through direct and non-profit self-governing local communities. However, this does not mean that it is not possible to obtain a concession for the commercial use of water. In accordance with Article 136 of the Slovenian Law on Water [17], a concession must be obtained for the use of water to produce beverages, and it can be obtained for a maximum of 50 years. In comparison, the Croatian legislative framework, as per your conclusion, is more stringent in granting concessions [15].

3.2. Pumping test and modelling

At the ***first location***, a pumping test was carried out to determine the hydraulic characteristics and properties of water flow within the aquifer. Prior to pumping, the groundwater level was measured, and during pumping, the decline in the groundwater level was monitored, correlating with the pumping volume. The hydraulic characteristics of the affected aquifer segment, the transmissivity coefficient (T) and hydraulic conductivity (k) were determined based on the collected data.

The hydraulic characteristics of the affected part of the aquifer are calculated using a formula that includes: decrease of groundwater level, pumping volume and time.

Prior to pumping, a check was made of the immediate surroundings of the location to determine that there are no pumping or aquifer recharge locations in the immediate vicinity (active wells, watercourses) that could significantly affect changes in the hydrogeological conditions at the micro location.

Conceptual model - For conducting the experiment and interpreting the results, the following assumptions were taken into account:

- The boundaries of the aquifer are far enough for them not to have influence on pumping;
- The aquifer is homogeneous, isotropic and of uniform thickness in the part affected by pumping;
- Before the start of pumping, the groundwater level in the area affected by pumping is approximately horizontal;
- The well is completely perforated in the saturated part of the aquifer and accepts the total horizontal flow of water;
- The flow towards the well is radial;
- Darcy's law applies;
- The usefulness of the well is 100%, there are no losses in the well;
- The hydraulic parameters of the affected part of the aquifer are constant.

Well capacity - The capacity of the well is the amount of exhausted water per unit of time, according to the formula (1):

$$Q = V/t \ (m^3/s) \quad (1)$$

Where: Q is the capacity [m^3/s], V is the volume of pumped water [m^3] and t is the measurement time [s]

The capacity of the well at the location is determined by the capacity of the pump whose declared capacity is 1200 l/min (20 l/s). During pumping, the water flow on the meter was monitored and the actual pumping capacity was determined, which is 15 l/s. The difference between the declared and measured capacity is caused by overcoming the pump delivery height. Q = 15 l/s (0.015 m^3/s).

On the ***second location***, only modelling was applied due to a significant reduction in the pumping rate. The current concession for the Pliva location allows for an extraction of 1,000,000 m^3 per year. Considering the existing pumping volumes, which are approximately 100,000 m^3 per year (only 10% of concessioned amount), a new concession will be obtained for pumping volumes of up to 100,000 m^3 per year.

Modelling of the groundwater level's response to pumping at the Pliva water pumping station was conducted for low water conditions over a 30-year period (rounded to 11,000 days). This duration represents the maximum term for which a concession can be obtained, to model a worst-case scenario.

The hydraulic conductivity values for the northern edge of the Zagreb aquifer system were taken from previous explorations [18], k = 0.4 cm/s (345.6 m/day).

With an average thickness of the saturated part of the aquifer measuring 3 meters and a hydraulic conductivity of k = 345.6 m/day, the calculated transmissivity T = 1036.8 m^2/day (12 $x10^{-3}$ m^2/s).

Groundwater levels vary between 112 meters above sea level (low water level) and 114 meters above sea level (high water level), respectively, between 8 and 10 meters below surface.

The MLU software was used to model the impact of pumping on the decline in the groundwater level in a single well, considering a maximum pumping rate of 411 m^3/day (equivalent to 150,000 m^3 per year, 17 m^3 /h, 5 l/s).

The MLU (Multi-Layer Unsteady state) Aquifer Test Analysis software was employed to model the impact of the well.

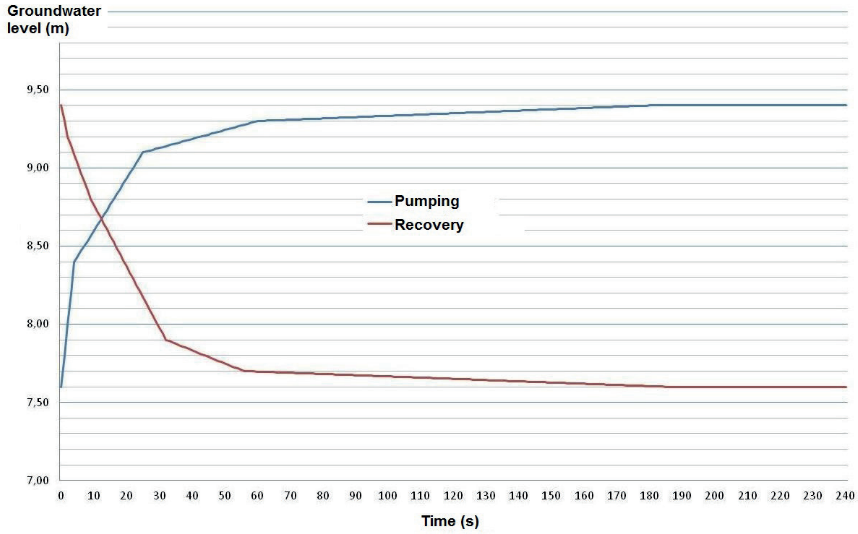

Figure 3: Display of decline in groundwater level during pumping and subsequent recovery [1].

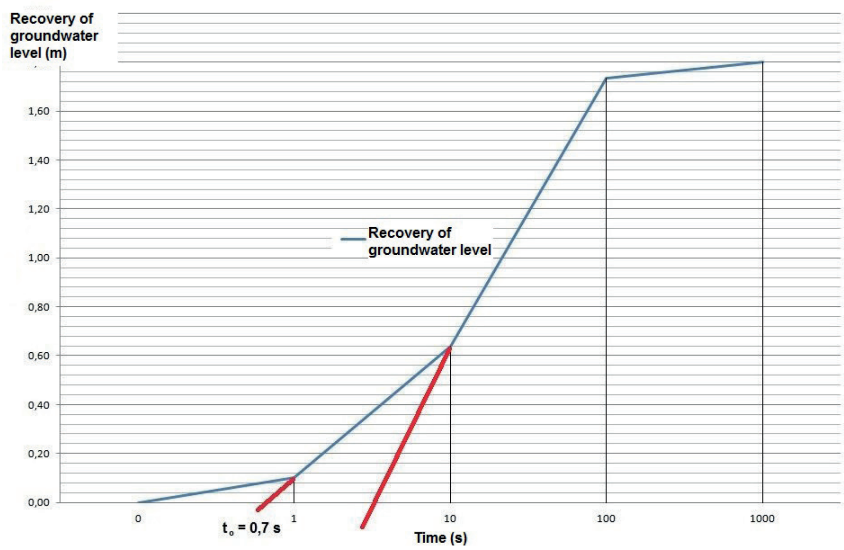

Figure 4: Jacob plot depicting the decline in groundwater level over time.

4. Results

4.1. Location 1 Results of pumping test

4.1.1. Results of pumping test

During the pumping test, water level experienced a decline of 1.8 m, dropping from -7.6 m below the surface to -9.4 m below the surface.

The water level stabilised during pumping after 170 seconds, indicating that a stationary flow had been achieved. After seizing the pump's operation, the water in the well returned to its pre-pumping level, a process that took 180 seconds [1].

4.1.2. Determination of hydrogeological parameters of the affected part of the aquifer

The hydrogeological parameters of the affected part of the aquifer were derived from the conducted test pumping, employing the Theis method, specifically designed for an unconfined aquifer.

Hydrogeological parameters were determined for two forms of pumping tests:

1. Pumping test with a constant pumping rate;
2. Recovery test involving return of water in the pumping well.

Calculation of the transmissivity coefficient:

The transmissivity coefficient is a hydrogeological parameter that describes the permeability of the aquifer (formula 1), and is equal to the product of the coefficient of the hydraulic conductivity (k) and the thickness of the saturated part of the aquifer (m):

$$T = k \cdot m \ [\ m^2/day,\ cm^2/s,\ m^2/s] \qquad (2)$$

Where *k* is the coefficient of hydraulic conductivity [m/day] and *m* is thickness of the saturated part of the aquifer [m].

4.1.3. Determination of hydrogeological parameters based on test pumping with a constant pumping quantity

The calculation of the transmissivity of the affected part of the aquifer during pumping was done graphically according to Jacob's method.

The direction of lowering of the groundwater level (s) is plotted on the ordinate (y axis) and time (t) in logarithmic scale on the abscissa (x-axis). In such a semi-logarithmic diagram, the entered values lie approximately on a straight line (Figure 4). On the line, the reduction (Δs) is determined for one logarithmic period, and the transmissivity is calculated according to the formula (2):

$$T = (2.3 \times Q) / (4p \times Ds) \quad (3)$$

In this study, a stable drop in the groundwater level was recorded in two logarithmic periods 1 - 10 s and 10 - 100 s. The transmissivity coefficient was calculated as the average transmissivity value for both logarithmic periods T_1 (1 - 10 s) and T_2 (10 - 100 s).

Decline data:

$$T_1 = (2.3 \times Q) / (4p \times Ds) = (2.3 \times 0.015\ m^3/s) / (4 \times 3.14 \times 0.8\ m) = 0.003434\ m^2/s \quad (4)$$

$$T_2 = (2.3 \times Q) / (4p \times Ds) = (2.3 \times 0.015\ m^3/s) / (4 \times 3.14 \times 0.8\ m) = 0.003763\ m^2/s \quad (5)$$

$$T = (T_1 + T_2)/2 = 0.0036\ m^2/s\ (311\ m^2/d) \quad (6)$$

From the value of transmissivity and the thickness of the part of the affected aquifer, the coefficient of hydraulic conductivity was calculated according to the formula (2):

$$k = T / m \quad (7)$$

$$T = 0.0036\ m^2/s \quad (8)$$

$$m = 15\ m – 7.6\ m = 7.4\ m \quad (9)$$

$$k = 0.00049\ m/s = 1.764\ m/h = 42.34\ m/day. \quad (10)$$

Storage S represents the volume of water released or received by the aquifer per unit volume of the saturated part of the aquifer for a unit drop in the groundwater level. In an aquifer with a free water surface, this value is approximately equal to the effective porosity (n_e).

When extending the line and intersecting the abscissa at s = 0, the intersection point coordinates are s = 0 and $t = t_0$. Inserting these values into Jacob's equation gives formula 11:

$$S = (2.25 \cdot T \cdot t_0) / r^2 \quad (11)$$

Where, r is 0.2 m and $S = (2.25 \times 0.0036\ m^2/s \times 0.7\ s) / 0.04\ m^2 = 0.14$.

Given that the Zagreb aquifer is unconfined, $n_e = 0.14 = 14\%$.

4.1.4. Determination of hydrogeological parameters based on recovery

Based on the recovery diagram (Figure 10), transmissivity and hydraulic conductivity were calculated according to Darcy's filtration law (Formula 5):

$$Q = k \times F \times I \quad (12)$$

Where, Q is the amount of water that flows through a given area in a unit of time, F is surface of the profile, k is the coefficient of hydraulic conductivity and I is the hydraulic gradient.

The recovery lasted 179 seconds, during which the water level rose by Ds is 1.8 m, the radius of the well is 0.2 m and the total volume of water in return, $V = (0.2\ m)^2 \times 3.14 * 1.8\ m = 0.23\ m^3$, therefore:

$$Q = 0.23\ m^3 / 179\ s = 0.0013\ m^3/s \quad (13)$$

$$Q = 0.23\ m^3 / 179\ s = 0.0013\ m^3/s \quad (14)$$

$$I = 1.8\ k = Q / (F \times I) = (0.0013\ m^3/s) / (2.26\ m^2 \times 1.8) = 0.00032\ m/s\ (27.65\ m/d) \quad (15)$$

The transmissivity was calculated based on the height of the saturated part of the well m = 7.3 m according to formula 1.

$$T = k \times m = 0.00032\ m/s \times 7.4\ m = 0.0024\ m^2/s\ (207\ m2/d) \quad (16)$$

Given that there was no data on well drilling - lithological composition and granulometry, the storage coefficient was calculated by including transmissivity in the formula (Formula 4):

$$S = (2.25 \times 0.0024\ m^2/s \times 0.7\ s) / 0.04\ m^2 = 0.095 \quad (17)$$

4.2. Location 2

4.2.1. Results of modelling

In case of maximum pumping rate, the drop in the water level in the well in a 30-year period will amount to - 0.7 m (Figure 5).

Considering that the ground water levels at the location are 1-2 meters higher than the lowest measured, the expected lowering of the water in the wells should be 20-30 cm less, i.e., from -0.4 m to -0.5 m.

The impact of pumping on the water surface will be visible only in the immediate vicinity of the well (up to 10 m), particularly under low-water conditions during prolonged continuous operation. Based on the information above, it can be inferred that extraction of ground water at the Pilva location, up to the maximum

Table 1: Hydrogeological parameters of the affected part of the aquifer obtained by pumping test.

Test	Hydraulic coefficient k (m/d)	Transmissivity T (m²/d)	Storage S	Effective Porosity n_e (%)
Pumping	42.34	311	0.14	14
Recovery	27.65	207	0.095	9,5

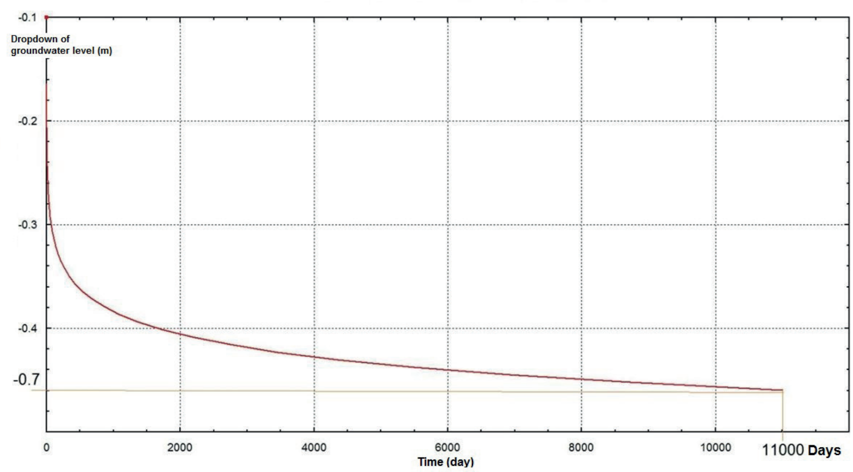

Figure 5: Groundwater level drop at Pliva site due to continuous pumping of 411 m³/day in 30 years in low water level conditions [2].

modelled quantity of 150,000 m^3 per year, is sustainable for a 30-year period.

5. Discussion

This paper highlights the application and significance of a geoscientific approach within the legislative framework for obtaining concession grants. Anyone acquiring a concession for the use of groundwater, whether through establishment or acquisition of a company, is required to transfer the concession. This involves submitting an application to the competent Ministry for the transfer of concession rights, as stipulated by Article 66 of the Law on Concessions [19]. It is crucial to note that obtaining a concession does not confer ownership of the water source, rather, it grants the right to extract defined quantities [15].

Every company that acquires concession rights also assumes the associated obligations outlined in the concession contract. Additionally, foreign companies seeking concession rights must establish a company in the Republic of Croatia, requiring them to employ the local population and automatically become taxpayers. The details of this process are also regulated by other laws not covered in this text, including the Law on Commercial Companies [20], the Law on Obligations [21] and others. The two examples presented in this paper are only a subset of the legal obligations [15].

To obtain a concession, every company should submit a hydrogeological study to the competent authority. The hydrogeological study should be performed by contractor competent in performing hydrogeological surveys and certified for such activities in compliance with the Ordinance [22].

There is no prescribed methodology for a hydrogeological study, the certified and competent contractor is responsible for evaluating existing data and prescribing additional surveys as needed.

According to the results obtained from Location 1, the hydrogeological parameters and the pump operation dynamics indicate that the maximum influence can only be visible in the immediate vicinity of the well.

At the Location 2, only modelling was employed, given the company's requests for a concession covering significantly lower quantities. It is crucial to highlight that the company is obligated to pay annual fees for the quantities granted in the concession, as these quantities are, in fact, reserved for company's specific purposes. Therefore, each company has a direct economic interest in minimising water usage, and subsequently, its exploitation.

The economics of water bottling, though not covered in this text, a less lucrative business than commonly thought. The obligations faced by the concessionaire partially answer the question of how a water bottling plant can fail to operate. The price of bottled water varies based on the packaging, and roughly amounts to 10 HRK (1.5 EUR) per liter, making it is about 500 times more expensive than publicly supplied water. It is essential to consider that besides concession fees, equipment, packaging, transportation, labour, marketing, margins, etc. also contribute to the overall price. In principle, the sale of bottled water only represents a fraction of the product range companies offer. Based on the review of key questions and answers within the regulation, it becomes evident that the commercial use of water resources is not in conflict with the public water supply. Examining the case of the Republic of Slovenia, where the right to drinking water is constitutionally protected, reveals that there are no legal obstacles for the commercial use of water. Moreover, concessions for commercial use can be obtained for as long as 50 years, a duration of 20 years longer than in the Republic of Croatia.

6. Conclusions

This paper outlines the process of obtaining concession grants for companies, using two examples where different approaches were performed for hydrogeological studies. Hydrogeological studies can be performed only by a certified contractor, given the absence of a standardised methodology due to varying aquifer types, exploration levels, exploitation histories, and other factors. As a result, the selected contractor must be competent to design and perform a hydrogeological study according to the requirements.

This procedure is essential for detecting and preventing potential negative impacts on the aquifer. Additionally, it serves as a crucial input for aquifer management, especially in cases of heightened demand for municipal water supply. This is the reason why the water resources cannot be privatised.

The fact that privatisation of water resources is not possible, does not mean that supervision and questioning of regulations by the public are not essential or desirable. Questions of this nature, highlight a growing public willingness to assume responsibility for the management of strategic resources, including drinking water.

Although occasionally misunderstandings and misinterpretations occur due to a lack of familiarity with the subject, geoscientists should welcome and support this trend through proactive participation. This involvement should include: education, clarification of legislative obligations and comparison of pumping quantities with those of the public water supply.

The delicate aspect is that geoscientists, especially if they serve as the expert witness, should be equipped to integrate two roles – scientific and legal - into a cohesive material understandable to decision-makers within the legal system.

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Conflicts of Interest: The authors declare no conflict of interest.

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Developing tools for a better incorporation of geoscientific knowledge in policy making for a densely populated region

Jasper Verhaegen [1], Shana Debrock [1], Jef Deckers [2], Roel De Koninck [2], Katrien De Nil [1], Katrijn Dirix [2], Helga Ferket [1], Bernd Rombaut [2], Renate Schoofs [1], Johanna Van Daele [1], Tom Van Haren [2], Jan Van Roo [1]*

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The need for a more efficient use of the subsurface in tackling a variety of issues is becoming more apparent, certainly in densely populated regions. For a better incorporation of geological knowledge into policy making, e.g., related to underground space use, raw materials management and (deep) subsurface planning for technologies such as geothermal energy, it is essential to develop user-friendly tools. These can translate geological information to field applications, which can be understood by policy officers, engineers, architects, etc. In Flanders (Belgium), such tools are developed and published on an open platform. Even though many tools are already available based on extensive 3D geological models, advances can still be made towards voxel models and 2D maps combining information for specific purposes.

La nécessité d'une utilisation plus efficace du sous-sol pour résoudre divers problèmes devient de plus en plus évidente, notamment dans les régions densément peuplées. Pour une meilleure intégration des connaissances géologiques dans l'élaboration des politiques, par exemple en ce qui concerne l'utilisation de l'espace souterrain, la gestion des matières premières et la planification du sous-sol (profond) pour des technologies telles que l'énergie géothermique, il est essentiel de développer des outils conviviaux. Ceux-ci peuvent traduire les informations géologiques en applications sur le terrain, qui peuvent être comprises par les responsables politiques, les ingénieurs, les architectes, etc. En Flandre (Belgique), de tels outils sont développés et publiés sur une plateforme ouverte. Même si de nombreux outils basés sur des modèles géologiques 3D étendus sont déjà disponibles, des progrès peuvent encore être réalisés vers des modèles voxels et des cartes 2D combinant des informations à des fins spécifiques.

La necesidad de un uso más eficiente de la subsuperficie para abordar una variedad de temas está siendo más aparente, especialmente en zonas densamente pobladas. Para una mejor incorporación del conocimiento geológico en el desarrollo de políticas, e.g., relacionadas con el uso del espacio subterráneo, manejo de materia prima y planificación de subsuperficie (profunda), para tecnologías tales como energía geotermal, es esencial el desarrollo de herramientas fáciles de usar. Estas pueden traducir la información geológica a campos de aplicación que puedan ser comprendidos por los encargados de gestionar las políticas de desarrollo, ingenieros, arquitectos, etc. En Flandes (Bélgica), esas herramientas son desarrolladas y publicadas en una plataforma abierta. Aunque ya existen muchas herramientas disponibles basadas en modelos geológicos 3D, se pueden crear nuevos desarrollos con modelamiento Voxel y mapas 2D, combinando información para propósitos específicos.

1. Introduction

The region of Flanders is one of the most densely populated regions of Europe, with a population density of 492 inhabitants/km² [1], compared to the European Union average of 109 inhabitants/km² [2]. The settlement area [3] in Flanders is 33 % of the total surface area [4]. In such a dense region there is significant stress on the available land surface area. Due to soil sealing by roads, housing, infrastructure, etc. the soil and the subsurface can no longer optimally carry out their natural geosystem services. This leads to a loss of biodiversity, reduced ground water recharge, the urban heat island effect, and more [5-8].

A shift towards a 3D perspective of our available space, thus incorporating the subsurface dimension, must be part of the solution, as density of functions can be increased in certain areas, while freeing land surface in others. The urban subsurface is considered a valuable, multifunctional natural resource that provides different (geosystem) services, such as groundwater, energy potential, geomaterials, carbon sequestration, heritage and underground infrastructures [5, 9, 10]. The use of the shallow subsurface for infrastructure purposes remains predominantly characterised by an ad-hoc, first-come, first-served, or last-resort approach [11-13]. This leads to scattered development of solitary projects, conflicts, competition, and unintentional consequences arising from unforeseen interactions with other underground services. Such practices are detrimental to the sustainable development of the urban environment and are likely caused by a lack of knowledge, foresight and planning [14-17].

A high population density requires a significant number of natural resources, leading to further depletion of groundwater levels and possible exhaustion of minerals and industrial materials. Ways to meet the demand include import, recycling, technological innovations and behavioural change [18, 19], yet domestic extraction of primary materials remains part of the equation [20]. Additionally, energy demand is high while available surface area for renewable sources such as wind and solar is limited. Geothermal

[1] Department of Environment & Spatial Development, Flemish Government, Koning Albert II-laan 20, 1000 Brussels, Belgium
[2] VITO, Boeretang 200, 2400 Mol, Belgium
* jasper.verhaegen@vlaanderen.be

energy provides a potential solution, however even the subsurface has its spatial limitations and planning of the (deep) subsurface is necessary to ensure an efficient exploitation of the available potential [21].

In this paper, multiple tools developed by the Department of Environment and Spatial Development of the Flemish Government and their relation to policy are presented. These tools are developed to unlock the subsurface potential for challenges related to underground space use, raw materials, and planning of the (deep) subsurface for emerging technologies such as geothermal energy.

2. Underground space use

As a result of the region's significant settlement area, Flanders has a high degree of man-made soil sealing [22] surfaces (15 % compared to an EU average of 2.3 % in 2006) [3, 23]. The high degree of soil sealing places a substantial strain on the environment, as soils are destroyed, and water can no longer infiltrate to replenish ground water levels [24].

To counteract these trends a shift in planning policy was instigated [25], which focuses on preserving open spaces and aims to halt urban sprawl by reducing the daily land consumption from six hectares in 2016 to zero hectares by 2040. Although the strategic vision briefly acknowledges the potential use of the subsurface to increase density, it lacks elaboration. In recent years an increasing number of municipalities and regions in Europe are becoming aware of the benefits of urban underground space (UUS) use [26], including the Flemish Government. Parallel to the development of the *Spatial Policy Plan Flanders* (2018), a policy exploration was launched to examine whether efficient use of UUS could be an additional solution for lowering the daily land consumption [27]. Cooperation between geo-scientists and urban planners is of utmost importance when developing subsurface policy. Ideally policy on subsurface infrastructures should be integrated in an overall vision/strategy of land use and urban planning, above and below the subsurface. In 2021 the Flemish Government launched the *fourth Flemish Strategy on Sustainable Development* [28], which includes an initiative aimed at sustainable UUS use. To aid the local and regional development of subsurface policy several tools/instruments are being launched such as a planning framework based on geosystemic considerations and

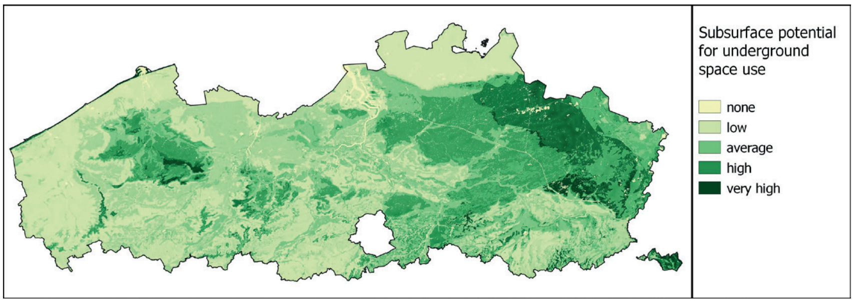

Figure 1: Map illustrating the subsurface's suitability for underground construction at depths ranging from 0 to 9 m below the surface. Suitability was calculated by incorporating information on settlement sensitivity of the (sub)soil, raw material potential, water saturation and pollution.

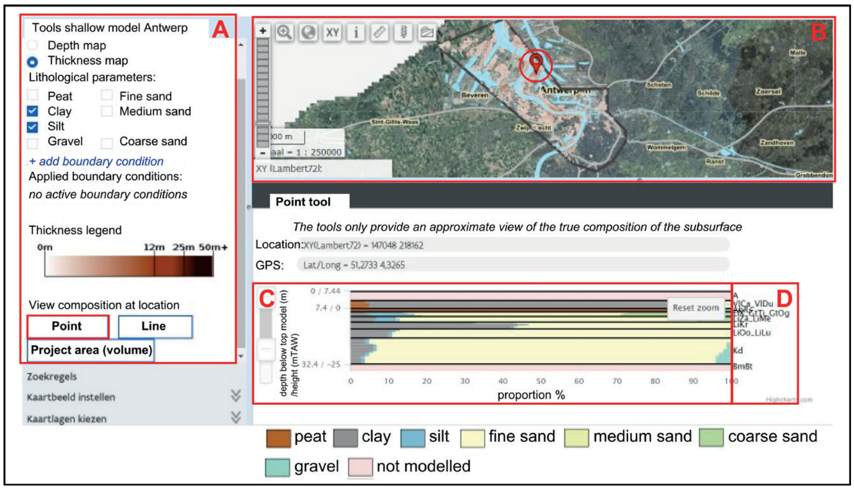

Figure 2: Image from the online viewer of the shallow subsurface voxel model of the Antwerp urban area, available on DOV [29]. (A) In the interface the user can choose to visualise a depth or thickness map and can choose which lithologies to visualise, together with secondary conditions such as minimal thickness of selected lithologies. Also, the point, line and volume calculation features are available. (B) The map shows the outline of the modelled area, in this example with a thickness map for the selected parameters clay and silt. (C) A 'virtual core' of the model is shown, at the location indicated on the map, in which the lithological composition for each voxel can be viewed, alongside the division into geological units (D). The key text was translated to English for the purpose of this figure, however the language of the online tool is Dutch.

an online policy guide for UUS planning.

In order to identify areas where underground space can be optimally developed, opportunity maps for underground space use are useful tools. Within Flanders, geologists, geographers, and policy makers are working together to develop a framework on the different surface and subsurface parameters to consider when promoting UUS. These parameters include the spatial context, settlement risk, raw material potential and geotechnical potential and associated risks [27]. These dimensions are combined and converted to simple maps, providing clear information about the potential of UUS in different areas of Flanders (Figure 1).

The open publication of subsurface 3D models, in combination with tailor-made and easy to use functionalities, raises subsurface awareness and enhances the understanding of policy makers, industry and citizens. This approach enables the exploration of the varied composition of the subsurface, thereby facilitating a more sustainable and effective management of the urban subsurface. Standard geological 3D models are layer-cake representations, dividing the subsurface into geological units. Nevertheless, it is crucial to note that, geological units are often not homogenous. To account for heterogeneity and to get a more detailed picture of the composition of the subsurface voxel models can be created. In these models, each voxel, or 3D pixel, has a value for certain parameters such as lithological composition. The Antwerp urban area and its port was chosen as the first test area to develop a shallow urban voxel model in Flanders [30]. The major infrastructure works in that area offered new field data and

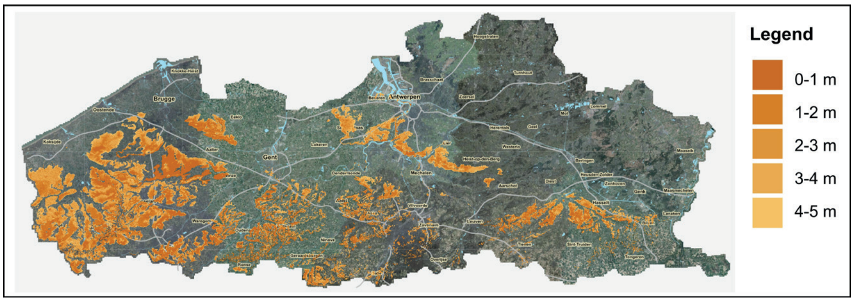

Figure 3: Map from the specialised DOV viewer [29] for the possible occurrence of swelling clays, showing the depth of the top of clayey Neogene or Paleogene units within the top 5 m below the surface.

the opportunity to refine the geological interpretations. In addition, these infrastructure works challenge environmental policy officers and project developers to increase their understanding of the composition and potential applications of the subsoil. The voxel model includes new data and geological insights, facilitating further knowledge building of Antwerp's subsurface. The dedicated online viewer enables geological, hydrogeological and geotechnical prospection and promotes the inclusion of subsurface data in geothermal projects, temporary dewatering, re-use of excavated soil, stability studies, infiltration projects etc. The variation in the lithological composition can be consulted at a point location or along a vertical profile (Figure 2). In addition, it is possible to calculate the volumes of the lithologies for various areas and depth ranges. Compositional information is given when querying the voxel model results.

Geological maps and models are also an important asset for regional risk mapping and management. The standardised data management of the composing elements in DOV (database of the subsurface of Flanders) [31] allows to derive hazard maps for different purposes at different scales, making them accessible to non-professional geologists. For example, certain geological layers consist, at least partly, of swelling and shrinking clays. On DOV, a map view for potentially swelling (sub)soils in Flanders is available (Figure 3) based on the geological 3D model [32] and the Digital Soil Map [33]. These clays can potentially cause damage to buildings due to fluctuations in water content, particularly of swelling clays such as smectite, found underneath foundations [34]. Further ongoing research should provide a preliminary risk map on swelling clays in the Flemish subsurface. The 3D distribution of these smectite-rich units, laboratory analyses of borehole samples, damage inventory, site investigations and geological expertise, enable a hazard assessment of the anticipated geological composition at a specific site. The results of this research should support the development of a more climate-resilient housing policy.

3. Raw Materials

In densely populated regions, such as Flanders, the demand on mineral resources is high, yet both the space and the public acceptance for new or existing quarries is very limited [35]. Raw materials extracted in Flanders are clay, loam, sand and gravel for the construction industry and white silica sand for glass and high-tech applications. The extraction is mainly regulated through the *Flemish Parliament Act on Surface Mineral Resources* (2003). This policy's basic objective is to have a sustainable supply of the necessary mineral resources to meet the current and future demand of society. In the periodically reviewed *General Surface Mineral Resources Plan (AOD)* [36], the reserves in the areas designated for mineral extraction are assessed in comparison to the demand for the raw materials, and proposals made for future actions are formulated. Required knowledge for the monitoring of mineral resources, in addition to the reserves, includes data on alternatives for the primary raw materials, production and use of all relevant materials and import and export flows. This information is periodically collected by the *Monitoring system for a Sustainable Surface mineral resources Policy (MDO)* [37]. For possible future scenario's, a stock-flow model is available.

Excavated geological layers, such as infrastructure projects are also potential resources. Developers are obliged to assess whether any economically valuable layers may be excavated during a project in advance, as these are an important alternative for primary sources from quarries.

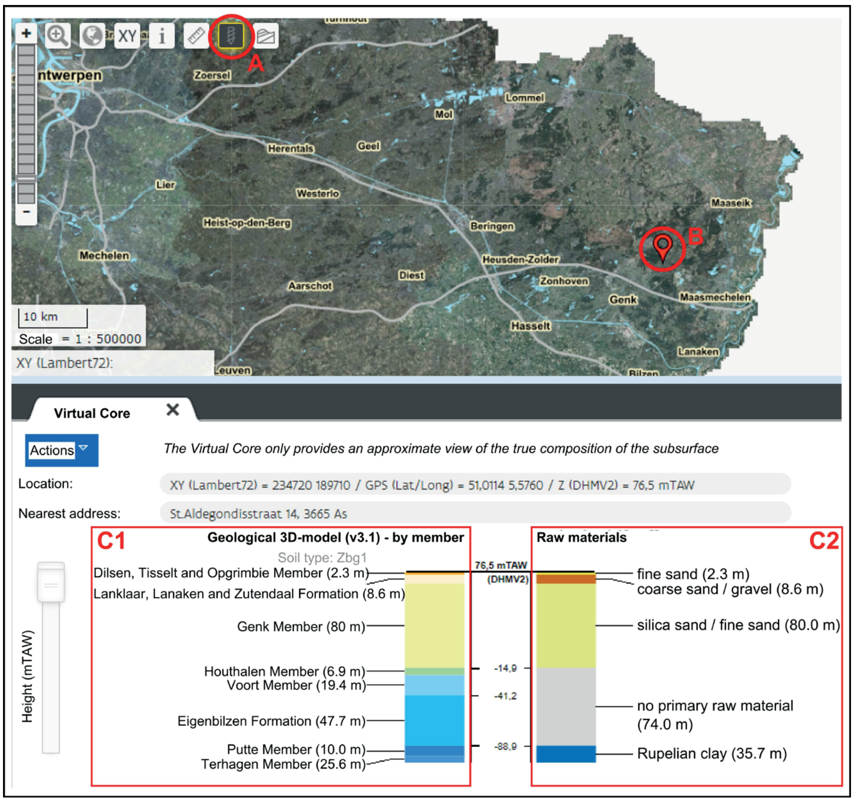

Figure 4: Visualisation of the raw materials model in the 'Virtual Core' of DOV [29]. The virtual core tool (A) can be selected at the top of the map viewer. With the tool an activated location on the map (B) can be selected. The result is shown below. In this example, the raw material model (C2) is compared to the geological members of the geological 3D model (G3Dv3.1) (C1). The key text was translated to English for the purpose of this figure, however the language of the online tool is Dutch.

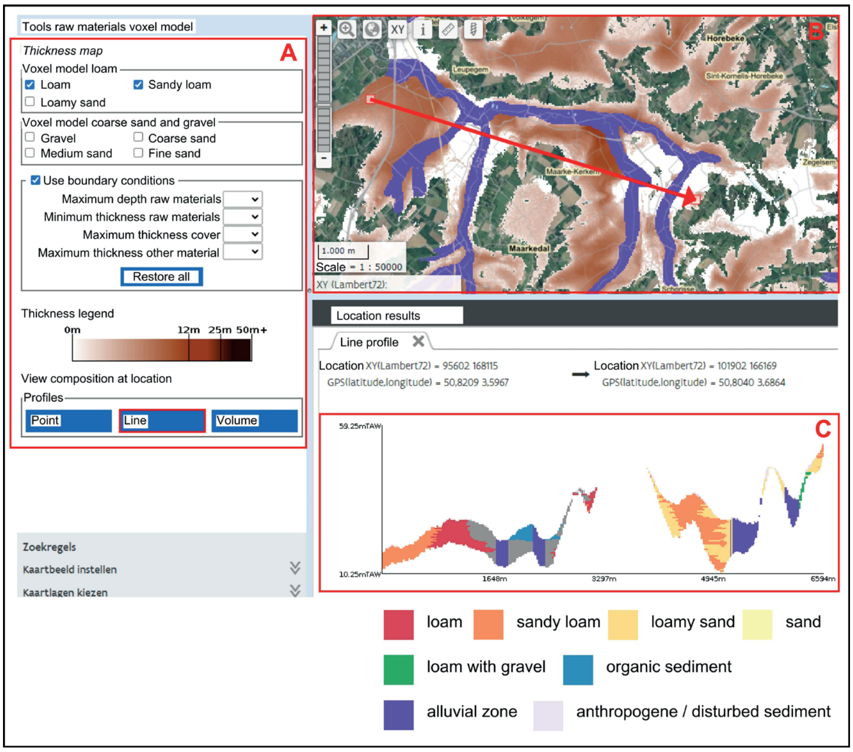

Figure 5: The specialised map viewer of the raw materials voxel models in DOV [29], with (A) the interface where lithologies of interest can be selected, as well as secondary conditions such as thickness of overburden, and the tools for point and line sections and volume calculations, (B) the map view with a thickness map of the selected lithologies – loam and sandy loam in this example – and a profile line added in this example with the result below, (C) where the vertical profile through the voxel model is shown, in which the Quaternary is divided into different lithologies. The key text was translated to English for the purpose of this figure, however the language of the online tool is Dutch.

Thanks to a detailed geological 3D model [32], which divides the subsurface into formally defined geological formations and members it is possible to make an educated estimate about the geological units present at any location in Flanders. In DOV tools like the 'Virtual Core' and 'Virtual Profile' are available which allow any user to visualise the geological composition of the subsurface, based on the available models, at any point or in a 2D transect along any line. Regarding existing and former quarries, there is also information available about which materials are being excavated and to which geological units these belong. Based on this information, a translation was made from the geological model to a raw materials model. The incorporation of this model into the 'Virtual Core' and 'Virtual Profile' tools, as well as presenting it as separate map layers for the shallow occurrence of each raw material unit, enables the possibility for quick assessment of the potential of valuable raw materials at any excavation site (Figure 4), which may then be selectively excavated and valorised.

For a more detailed and accurate representation of the subsurface from a raw materials perspective, two voxel models were created for materials with a shallow and geographically confined occurrence. One in the southern part of the region, where loamy aeolian deposits occur close to the surface [38] and another in the east of Flanders, where coarse sand and gravel units related to the Rhine and Meuse rivers occur at shallow depth [39]. A specialised map viewer was developed in DOV for these models, along with tools, such as virtual core, profile and volume calculations (Figure 5). These models enable companies already active in quarrying materials to locate the best deposits. They also allow infrastructure companies to assess whether any valuable materials may be excavated during a certain upcoming project, although confirmation through field research remains necessary.

4. Planning of the deep subsurface

The subsurface can play a key role in the energy and climate transition by adding geothermal energy, hydrocarbon storage and heat storage to the energy mix. Not only does the subsurface contain energy sources in itself, but it also offers large reservoir spaces where energy deficits or overproduction from (renewable) sources at the surface can be buffered on seasonal scale [40]. Geological layers with suitable characteristics and conditions for these applications, mainly the lower Carboniferous limestone, are not equally distributed in Flanders, leading to pressure on the available space and competition at depth. A thoughtful vision for subsurface allocation is essential for an optimal deployment of subsurface applications and to preserve its potential for future generations. The *Flemish Decree on the deep subsurface* (2009) contains rules for efficient planning. Exploration and exploitation volumes need to be strictly delimited in three dimensions based on an acceptable subsurface impact radius, so to avoid negative impacts on neighbouring activities while being as efficient as possible. Stacking of volumes and combining activities is allowed under certain conditions (Figure 6). Nearby projects need to tune their operational works. If required, the Flemish Government can intervene in the collaboration to ensure efficient use of the subsurface. The decree also stipulates that a structural vision for the deep subsurface needs to be developed. This instrument is in development and will foresee a complete overview of the legal aspects, Flanders' geology, an inventory of potential applications with their boundary conditions, active permits, time and space relationships of all potential activities and an assessment framework. The latter aims at providing insights into the opportunities and challenges of the deep subsurface and into the impacts of certain policy choices. Policy makers will be able to use this assessment framework as base for their policies. This structural vision is not legally binding, nor is it a subsurface register which stipulates what should be done at each location. However, it is a strategic ex ante instrument which can help in concrete permit decisions to avoid ill-considered ad hoc destination which could jeopardise the needs of current and future generations.

Being efficient in a densely occupied subsurface requires detailed geological knowledge. In addition to the implementation of the Flemish Decree on the deep subsurface, a three dimensional layer and fault model is being developed for the deep subsurface [32, 41] and targeted research assignments are commissioned regularly to increase knowledge and insights on the geology, the valorisation potential

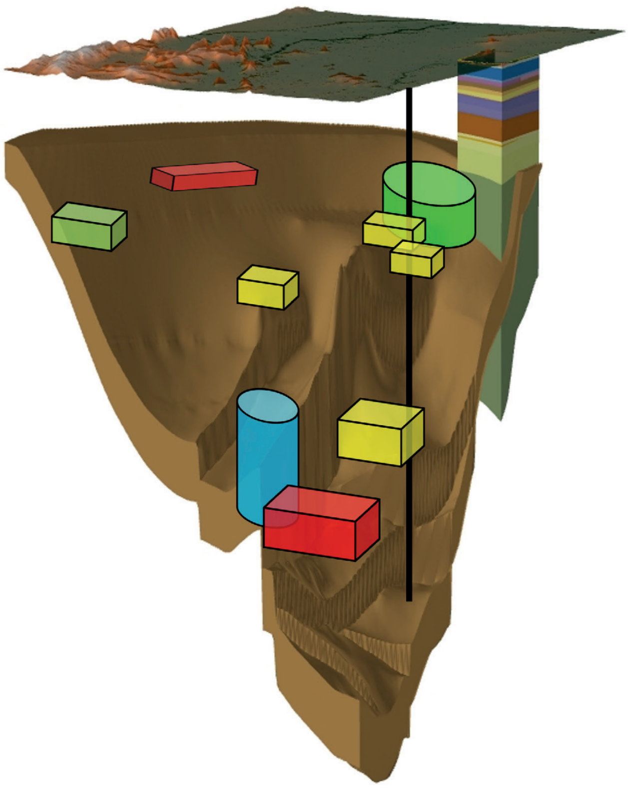

Figure 6: Schematic illustration of the principle of 3D permits whereby different applications may occur next to or above each other. Geological visualisation of the Campine Basin, with the Devonian layer at the base (brown) on top of the London-Brabant Massif, in which the deepest subsurface applications in Flanders are possible. The model column shows a cross-section through the 3D geological model from base to top.

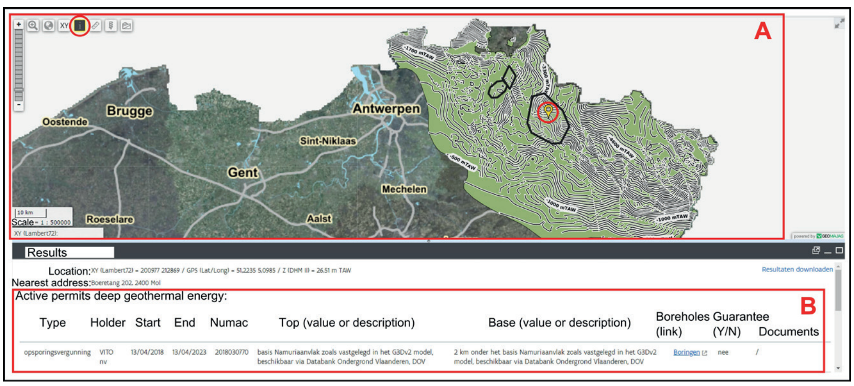

Figure 7: Map view in the DOV viewer [29], illustrating (A) the occurrence of the Dinantian limestones (in green), in which multiple applications such as geothermal energy, gas storage and carbon storage are possible, overlain with the isohypses of the top of the Dinantian, both based on the G3Dv3.1 geological 3D model. The active permits for deep geothermal energy are also shown on top. By clicking on these layers more information can be gathered, such as shown below (B) for the active permits, e.g. type of permit, start date, end date, top, base, related cores and coupled documents. The key text was translated to English for the purpose of this figure, however the language of the online tool is Dutch.

of the subsurface, geohazards associated with subsurface development and other aspects for an efficient and responsible management of the subsurface [42]. Both geological information as well as administrative information on existing permits is made publicly available through DOV (Figure 7), where governments and private companies can gather information for the exploration of possible future opportunities.

5. Future perspectives

As one of Europe's most densely populated regions, Flanders will continue its current trajectory towards better surface and subsurface planning and a more optimal management of its resources. As demonstrated in this article, geological knowledge is becoming increasingly important for the realisation and implementation of policies related to multiple domains, such as resources, energy, spatial planning, and climate. Even though an interesting set of tools has already been developed, there is still room for improvement. In the future more focus must be on a better translation of geological knowledge towards field applications, which can be readily understood by non-geoscientists such as policy officers, engineers, architects, etc. In order to achieve this, the current well-developed regional 3D layer model of the subsurface should be converted into a voxel model, which can be filled in with multiple parameters, e.g. related to geotechnical, geothermal or hydrological properties. Easy to interpret 2D maps combining multiple types of geological and other data to show applied information for specific use are perhaps the best tools for communication with non-experts. Of course, continued investment in new data and geological knowledge remains key for the creation of better maps and models. Lastly, a better integration must be realised between surface and (deep) subsurface information to incorporate the subsurface dimension into planning processes and to gain more insight into both the opportunities and risks related to the subsurface, which can be used in an earlier phase of planning processes thanks to accessible geological tools.

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News corner:
Compiled by Anita Stein, EFG Secretariat

Elevating the Geoscience Profession is Crucial to Tackle Society's Most Pressing Challenges

EFG Unveils New Strategy and Modern Identity

EFG announces the release of a new strategy for the period 2023-2027 aimed at promoting excellence in the application of geoscience across Europe.

As the geological organisation of choice for National Associations throughout Europe seeking representation within the EU, and for policymakers in search of expertise, we aim to be recognised globally through our international network of partnering organisations. We aspire to be respected as a federation steeped in values that sustainably balance the needs of all humanity with those of our planet.

As part of our new strategic plan, we underwent a significant rebranding process and are proud to reveal our new logo, which symbolises inclusivity and the multifaceted nature of Earth.

As stated by EFG President David Govoni, "The new logo represents much more than a simple graphical exercise. It is the culmination of a complex process, incorporating insights from both our council members and external stakeholders. Beyond its aesthetic transformation, the logo signifies a profound shift and holds a deeper meaning. It is a strategic element that aligns seamlessly with our evolved vision and will play a pivotal role in delivering the outcomes outlined in our new strategy."

European Federation of **Geologists**

New logo of the European Federation of Geologists.

More information: ***http://tinyurl.com/bd7x939r***

Geology Plays Crucial Role in Light of UAE Consensus

The European Federation of Geologists (EFG), in collaboration with the Italian National Council of Geologists (CNG), advocated for the indispensable role of geosciences in addressing global climate challenges during the recently concluded COP28 in Dubai.

As COP28 concluded, on 13 December 2023, with the historic UAE Consensus making an unprecedented reference to transitioning away from all fossil fuels and envisioning a global goal to triple renewables and double energy efficiency, the role geologists play in climate action is ever more crucial. EFG, alongside its Italian member, the CNG, prominently represented the geoscience profession at the Conference of the Parties (COP).

Geologists, through their study of climate change impacts on natural hazards such as landslides, coastal erosion, earthquakes, and sea-level rise, play a pivotal role in addressing some of society's most pressing issues. These also encompass the access to renewable energy sources, mineral supply, and water management. Geologists are instrumental in advancing most of the Sustainable Development Goals (SDGs), ensuring resilience to environmental change and geological hazards for people, jobs, and infrastructure.

EFG Global Ambassador Maureen Gallagher introducing innovative geoscience projects funded by the European Union during COP28 in Dubai.

Lack of Awareness about Geology at COP28

Despite the critical role of geology for society, the presence of geological topics at COP28 was dispersed, offering limited opportunities for interaction. For instance, conversations on vital issues like critical raw materials for the energy transition were underrepresented, and discussions on hydrogen and geothermal energy lacked interlinkages.

Surprisingly, a significant number of COP participants lacked awareness of the role of geology in the energy transition. As EFG President David Govoni underlined, "this lack of understanding hampers the effectiveness of overall climate strategies, as geologists play a crucial role in the early stages of the energy supply chain."

Regarding the pivotal role of geology in the energy transition, CNG President Arcangelo Francesco Violo stated, "there is an urgent need to focus on new renewable energy sources to reduce greenhouse gas emissions with 43 percent by 2030 and 60 percent by 2035, so that the net zero 2050 goal can be realised. Geothermal energy, as a renewable and clean resource," Violo continued, "can and must serve that purpose".

EFG and CNG are therefore calling for a stronger focus on raw materials, underground storage of CO2, deep geothermal sources, and land use planning.

Professional Geologists as Catalysts for Climate Action

Adhering to high professional and ethical standards in the application of geology has the potential to expedite change in climate action in the short-term and can significantly support the objectives outlined in the UAE Consensus. EFG and CNG accordingly call for increased support in training and recruiting the workforce needed for the energy transition, while also educating the next generation of geologists to avoid a future skill force gap.

International certifications such as the European Geologist professional title, conferred by EFG, provide a valuable tool for the accreditation of professional quality. It facilitates the international mobility of geoscience professionals, helping to address workforce shortages. In this context, the European Federation of Geologists and its national association members can serve as transversal bodies through the active involvement of geoscience professionals in academia, industry, public agencies, and governments.

Call to Action for COP29

To pave the way for a heightened awareness of geological topics at upcoming Conferences of the Parties, EFG and CNG jointly call for a dedicated Critical Raw Materials (CRM) Day at COP29 in Azerbaijan in 2024. This initiative urges the support of the European Union (EU) and non-member states. Additionally, EFG and CNG advocate for the establishment of a CRM pavilion spanning the entire COP timeline, in collaboration with all partner organisations.

Congratulations to the winners of this year's photo contest!

EFG and our partner organisation EAGE, the European Association of Geoscientists and Engineers, are honoured to announce the winners of the 2023 Legends of Geoscience photo contest!

The first place goes to Nazmus Zaqeb, with his photo 'Plastic recycling worker in Bangladesh,' taken in Rangpur, Bangladesh.

The second place went to Ayesha Ejaz, for her photo 'I need some mountain time' taken in Khunjerab Pass, Pakistan. The third place was given to M.A. Omar Naseef, for 'Gardmore River' taken in Sri Lanka.

Congratulations to the winners, and thanks to everybody for voting for this year's 'Legends of Geoscience'!

Nazmus Zaqeb, Plastic recycling worker in Bangladesh, Rangpur, Bangladesh.

Ayesha Ejaz, I need some mountain time, Khunjerab Pass, Pakistan.

M.A. Omar Naseef, Gardmore River, Sri Lanka.

Submission of articles to European Geologist Journal

Notes for contributors

The Editorial Board of the European Geologist journal welcomes article proposals in line with the specific topic agreed on by the EFG Council. The call for articles is published twice a year in December and June along with the publication of the previous issue.
The European Geologist journal publishes feature articles covering all branches of geosciences. EGJ furthermore publishes book reviews, interviews carried out with geoscientists for the section 'Professional profiles' and news relevant to the geological profession. The articles are peer reviewed and also reviewed by a native English speaker.
All articles for publication in the journal should be submitted electronically to the EFG Office at ***info.efg@eurogeologists*** according to the following deadlines:

- Deadlines for submitting article proposals (title and content in a few sentences) to the EFG Office (***info.efg@eurogeologists.eu***) are respectively 15 July and 15 January. The proposals are then evaluated by the Editorial Board and notification is given shortly to successful contributors.
- Deadlines for receipt of full articles are 15 March and 15 September.

Formal requirements

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- Title followed by the author(s) name(s), place of work and email address,
- Abstract in English, French and Spanish,
- Main text without figures,
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Abstract

- Translation of the abstracts to French and Spanish can be provided by EFG.
- The abstract should summarise the essential information provided by the article in not more than 120 words.
- It should be intelligible without reference to the article and should include information on scope and objectives of the work described, methodology, results obtained and conclusions.

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- The main text should be no longer than 2500 words, provided in doc or docx format.
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- Please limit the use of footnotes and number them in the text via superscripts. Instead of using footnotes, it is preferable to suggest further reading.

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Illustrations

- Figures should be submitted as separate files in JPEG or TIFF format with at least 300dpi.
- Authors are invited to suggest optimum positions for figures and tables even though lay-out considerations may require some changes.

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- EFG website, ***www.eurogeologists.eu***
- GeoNews, a monthly newsletter with information relevant to the geosciences community.
- European Geologist, EFG's biannual journal. Since 2010, the European Geologist journal is published online and distributed electronically. Some copies are printed for our members associations and the EFG Office which distributes them to the EU Institutions and companies.

By means of these tools, EFG reaches approximately 45,000 European geologists as well as the international geology community.

With a view to improving the collaboration with companies, EFG proposes different advertisement options. For the individual prices of these different advertisement options please refer to the table.

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